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NASA'S ROLE IN AERONAUTICS: A Workshop

Volume VII Background Papers

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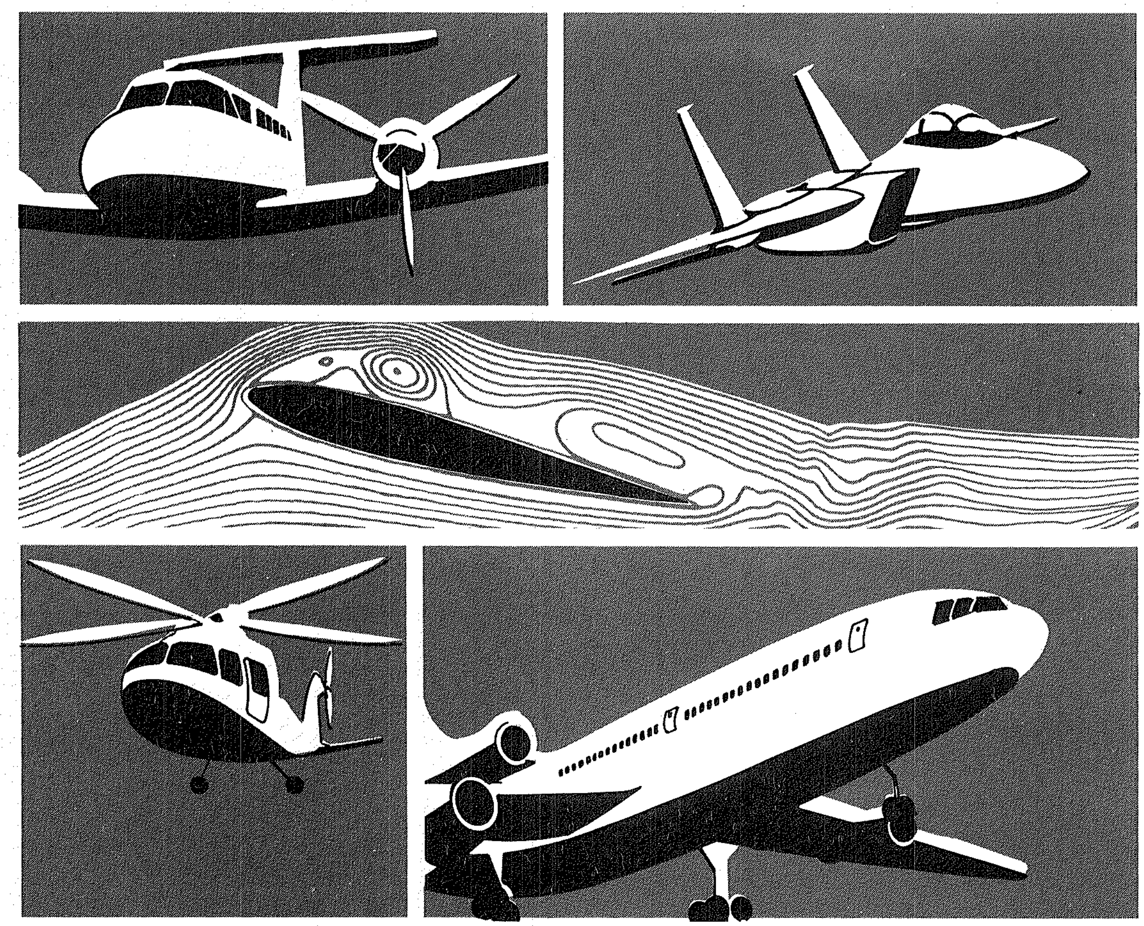

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WORKSHOP ON

ROLE OF NASA IN AERONAUTICS

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PREFACE

Aeronautics is changing in many significant respects. The implications of this are so far-reaching as to call into question the future position of the United States in world aviation.

The magnitude of this question, with its possible consequences for the nation's economy and security, led the National Aeronautics and Space Administration (NASA) to seek an independent evaluation from the Aeronautics and Space Engineering Board (ASEB) of the National Research Council's Assembly of Engineering. Specifically, the ASEB was asked to assess the nature and implications of the current state of U.S. aviation in a world setting and their significance for NASA's role in the nation's aeronautical future.

The ASEB responded by convening a workshop July 27 through August 2, 1980, at the National Academy of Sciences' Woods Hole Study Center. The workshop was structured into four panels covering military aviation, transport aircraft, general aviation, and rotorcraft. In addition, an overview panel was formed to consider NASA's role in research as well as its relationships with other elements of the aeronautics community.

The central task of the workshop was to examine the relationship of NASA's aeronautical research capabilities to the state of U.S. aviation and to make recommendations about NASA's future roles in aeronautics.

NASA and its predecessor, the National Advisory Committee for Aeronautics (NACA), traditionally have maintained a cooperative relationship with the aeronautical industry, with other government agencies concerned with aircraft operations and regulations, and with the academic community engaged in aerospace research. This triumvirate was taken into account in planning the workshop and selecting the participants. Thus, representatives from each part of the aeronautical community were invited, and information on NASA's relationship with each was the subject of special presentations prior to the working sessions. Representation from industry was predominant because industry's relationship with NASA is considered to be a key element in examining the present and future roles of NASA.

The members of the workshop panels represented, in total expertise and experience, all of the important sectors of aeronautics: military

aircraft and missiles; commercial air transports; general aviation; rotorcraft; university and private research; airline operations; and government regulatory agencies. In addition, the participants also included representatives of other industries--notably, automotive, electronics, and steel. Including the speakers and other nonpanel members, close to 80 individuals participated.

The participants were asked to address the issue of NASA's role in the context of a wider discussion concerning: the status and dimensions of U.S. aeronautics; the key aeronautical problems and opportunities that are likely to be amenable to research and technology development; the historical evolution and accomplishments of NASA in aeronautical research and technology development; and possible alternatives to NASA. Each of these subjects is discussed thoroughly in separate panel reports.

The report of the workshop consists of seven volumes:

I -- Summary

II -- Report of the Panel on Military Aviation

III -- Report of the Panel on Transport Aircraft

IV -- Report of the Panel on General Aviation

V -- Report of the Panel on Rotorcraft

VI -- Report of the Overview Panel on Aeronautical Research

VII -- Background Papers--The Outlook for Aeronautics and Relevant Areas

In order to help focus the discussion, NASA officials developed and provided a concise set of definitions of eight possible roles for NASA: <u>National Facilities and Expertise</u>; <u>Research</u>; <u>Generic Technology Evolution</u>; <u>Vehicle Class Technology Evolution</u>; <u>Technology Demonstration</u>; <u>Technology Validation</u>; <u>Prototype Development</u>; and, <u>Operations Feasibility</u>. Because some of these roles differ, depending on the aeronautical discipline involved, the roles are assessed within six principal aeronautical disciplines: <u>aerodynamics</u>, <u>structures and materials</u>, <u>propulsion</u>, <u>electronics and avionics</u>, <u>vehicle operations</u>, and <u>human engineering</u>. Definitions of these roles and disciplines are contained in Section IV of Volume I. The matching of the roles and disciplines is treated in Volumes II-VI and summarized in Section II of Volume I.

The workshop participants were extensively briefed by officials from NASA, the Department of Defense (DOD), and the Federal Aviation Administration (FAA), by leaders from the aviation manufacturing and operating industries, and by a member of Congress.

Each panel separately considered the national benefits produced within the dimensions of its sector and the relative state of the sector's world position; each considered the evolution of NASA's role, as well as a rationale for NASA's aeronautical support of its sector; and, finally, each panel produced sector-oriented conclusions and

recommendations for NASA's roles for the future. Although there are obvious overlaps, the similarities and differences in each of the panels' findings are preserved in the separate reports of the sector-oriented panels, Volumes II-V.

This document, Volume VII, contains the Background Papers that were presented to a plenary session of the workshop on the first and second days.

Each paper is the work of an individual who accepts full responsibility for its contents. Each speaker was invited to deliver his paper because of his recognized competence in the subject. None of the papers published in this volume has been critically reviewed in accordance with the procedures approved by a Report Review Committee of the National Research Council, which operates on behalf of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The Aeronautics and Space Engineering Board is grateful to the speakers, all of whom gave so willingly and generously of their time and expertise to bring to the workshop participants a wealth of knowledge and insight on issues likely to affect on the future course of aeronautics in the United States.

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BACKGROUND AND QUESTIONS ON NASA'S ROLE IN AERONAUTICS

Dr. Robert A. Frosch
Administrator
National Aeronautics and Space Administration

Art Buchwald enunciated what is known around Washington as Buchwald's theorem when he said that the way to succeed in Washington is to fail. Having observed the Washington scene for a while, he concluded that it was precisely those portions of the government that failed in solving problems that received the greatest attention. Therefore, those problems must be terribly important and they must have more money in next year's budget to try again to solve those problems. I suppose my corollary to Buchwald's theorem is that the way to fail in Washington is to succeed. In some sense, that is an introductory statement to this workshop.

For over 60 years we have had a research and development operation within the U.S. government that has maintained a close working relationship with private industry. We have succeeded jointly in the sense that, over a period of time, the U.S. aeronautical community founded, constructed, and came into domination of a world aeronautical industry. That, I think, is strong evidence of success. In some sense, that very success has led, in the past several years, to a questioning of the basis and procedure upon which that success was based. We have gone through a period in which the very nature of the NASA program in aeronautics, the relationship with industry, and the fact that there was a funded program have been questioned both during the budget process and a number of policy formulation processes. We are continually being asked in very blunt terms, "Why does the U.S. government do research and development that subsidizes a wealthy industry?" I am putting it in its sharpest and strongest terms. This is a question we are asked frequently.

I would say that the Congress is a bit schizophrenic on this point. Some subcommittees and committees and members are strongly in favor of even more aeronautical research and development. Some take the view that I have just described.

So, we are precipitated by the outside-of-NASA climate into

examining this whole question of what the policy of NASA, industry, and the academic world ought to be in regard to each other in the future. Of course, it is not wholly a bad thing to go back and reexamine the basis upon which we are working and the policies and the boundary lines between various kinds of work.

The specific charter for what we are doing is a legislative charter. It is the Space Act of 1958, which, like most organic acts, is specific but vague. In order to decide what you have to do, you must do a good deal of interpreting. It is clear that NASA is charged with doing research and development to ensure U.S. leadership in space and aeronautics. However, since nobody knows precisely what leadership in either of these subjects means, it gives us a good piece of rhetoric but doesn't carry us very much farther. It is clear that we principally have a civil responsibility, but we also have a responsibility for working with and supporting, as well as being supported by, the military side of the aeronautics and space business.

Beyond that, there is relatively little guidance other than that it is a research and development charter.

All parties seem clear on the fact that we should not be in the business of designing or building commercial aircraft or building prototypes. All parties seem clear that we should be in the business of basic research in aeronautics. Nearly everything else is in some sense in contention. So, one way to put a class of questons to this group is to say, "Where are the boundary lines, or in what areas between pure aeronautical research and the actual construction of prototypes or final flying machines should the NASA program reside? How should it span that set of possible areas? What is the relationship of the government-owned facilities to the academic facilities? How shall those relationships be preserved? What is it that NASA should be trying to do as its specific role in the whole business of civil aeronautics and in its relationship with military aeronautics?"

This is not an academic exercise for us in any sense of the word. It becomes very real in the course of the next month or two as we try to decide what the fiscal 1982 budget for NASA in aeronautics ought to be, and what activities it should include, and what activities it should exclude. I don't, by that remark, mean to say that this is a prebudget exercise for the 1982 budget, but I do want to put both an immediate and a long-range policy realism on it because every year we have an opportunity, in the course of developing the rationale for the budget, to decide what the rationale is for future operations and future budgets.

Having established a general framework, I would like to say that your willingness to come and spend a week working on this problem is our strongest indication that the industry and the academic world are interested in what we do and think there is some importance to it. I want to thank you for taking the trouble and effort in coming together to help us try to rethink what the NASA role is in aeronautics, which is the general charge for the week. Thank you.

NASA'S ROLES AND CONCERNS

Alan M. Lovelace
Deputy Administrator
National Aeronautics and Space Administration

I would like to share some views and perceptions on where we are domestically, where we are in the military, civil aeronautics activity as viewed from NASA, where we are on the international scene, and finally a few remarks on the legislative environment around us. Then, finally, at the risk of some repetition, pose some of the questions that are on our minds.

The current U.S. aeronautical research and development environment seems to have in it a number of positive and some negative factors, as viewed in the time frame of this meeting. Surely, advances in computer technology have dramatically shortened the time required for design and design optimization. It is such that we can now evaluate quickly and economically large numbers of design options featuring new technological advances and pick the best combinations, then move into equally efficient computerized detailed design and production processes. These are clearly advances in our business, many of which are of relatively recent origin. This improved analytical capability enables us to reduce the number of design variations so that experimental testing can be limited to the key problem areas identified. New materials and fabrication processes have made it possible to take advantage of many attractive aerodynamic and structural concepts that were not practically possible as recently as 10 years ago.

There is no question in my mind that our U.S. industry still leads the world in its ability to apply new technology to attractive designs and the matching of those designs to the market needs. They are able to convert these designs quickly and efficiently into top-quality, highly reliable products, and to back up these sales with first-rate product support. Clearly, one area of management technology that we still, I think, lead in in the United States is the management of large, complex systems. The alacrity of the U.S. industry decision

process in arriving at optimizations that match the market requirements represents a substantial advantage.

There are some negatives, however, that should be pointed out. If one looks at our U.S. aeronautical industry vis-à-vis particularly the Europeans, it is fair to say that after World War II we had essentially led in all areas and that that lead is rapidly shrinking today. The cost and complexity of developing new aeronautical systems have virtually skyrocketed. There have been increases in the severity of environmental and safety requirements imposed upon designs which have, in turn, led to additional development cost burdens and have created additional needs for proven technology. The development cost and risk questions that face our industry, coupled with warranty requirements, questions of product liability, and customer conservatism, make it extremely difficult, if not in some cases impossible, to incorporate unproven, new technology no matter how attractive the technical benefits may appear. This has been coupled, in many cases, with a need for coproduction agreements and international understandings in order for our industry to compete effectively in foreign markets. It has also led to concerns regarding such questions as technology transfer from the United States to many of our foreign commercial competitors.

Let me make a few remarks regarding the civil-military aeronautical requirements. I think it is certainly true that the military business bolsters most of our commercial manufacturers in terms of core staffs, facilities, financial stability, and independent research and development support and contributes substantially to the overall know-how that resides in our industries as well as in our universities. Basic technologies and even hardware are similar in many areas and apparently in many areas are nearly identical. Nevertheless, the military requirements are often more demanding and provide effective drivers for technological advancement. The military aircraft tanker and the utility aircraft can provide, in some cases, additional markets for modified commercial products.

It would seem in the near term that the budgets for military research and development may see some growth. The question of course remains as to where those investments will be made. The requirements in terms of operational forces are very large and even though many of the budgets of the Department of Defense (DOD) departments in aeronautics will grow, there remains the question of growth in the research and development portions of those budgets.

On the negative side, the military programs face the same obstacles to incorporation of new technology as the civil systems in terms of cost and inability to accept the risk of finding themselves dependent on unproven aerospace or aeronautical advances. As a consequence, they must focus as best they can on their military requirements with generally near-term and proven technology. Long lead times and budget pressures have, in many areas, almost eliminated experimental aircraft from many of the military programs. This concern has in the past driven NASA and the DOD to engage in experimental aircraft development where it was required by the nature of the technologies in question.

The civil aircraft requirements, even where missions are superficially similar to the military, are often very different and require different technological development and emphasis. For example, civil usage entails vastly greater numbers of annual and total flight hours on their systems, whereas in the military case the economy and mission performance are important, but primary emphasis must be placed on the performance aspects and then on the economies of performance for those systems. Military priorities, of necessity, must favor their combat missions and, thus, developments of transport types in recent years have been extremely rare in the research and development programs of the military and have not, in the recent past, presented the opportunity for try-out of commercially applicable new technologies.

Let me turn to the international situation. Our allies have become much stronger in the past 10 years and have the technical know-how, the production capability, and the desire to participate as full partners in mutual defense, including development and production of military aeronautical systems. They have experienced great economic growth, which has not only provided the ability to support their military systems, but has also created civil transportation demands and corresponding domestic commercial markets for their aircraft industries. The Europeans have achieved these gains in part by pooling resources and by developing partnerships in technology, development, and production. They have worked cooperatively with many American companies on major production programs, sharing investments, strengthening access to markets, and, in some instances, even providing production economies.

A somewhat newer and growing factor to be considered from the international scene is the matter of utilizing aeronautical technology and development as a trading stock. Many nations are emerging today that want to achieve a level of technological independence, not the least of which is China. They are looking not just to the United States, but to many other countries to help piggy-back their growth. Some countries are catching up with the state of aeronautical research and development in the United States. All of these factors have tended to make them very formidable competitors in the world market. In most instances strong government support is provided in various forms ranging from the support of research and development down to what must be concluded as being direct subsidy of their industries and of their research establishments. In some countries aeronautical industry employment is maintained simply as a national policy and the consequences of that, I think, are clear to each of us. In other areas, strong ties are maintained with emerging nations, including former colonies, and some of these Third World countries may in fact represent significant future markets. The technology edge that we speak of is meaningful, I believe, only when that technology is applied to a product. If obstacles to technological application or innovation in the United States are real and cannot be overcome, then technology cannot be used effectively by the U.S. industry to offset nontechnical advantages of their foreign competitors.

Let me just remind you of some of the legislative activities that impinge upon the deliberations of this group. The final returns on deregulation are not all in, but it seems so far to have stimulated competition, putting a premium on cost reduction and creating additional markets for new classes of aircraft such as the computer aircraft market. Deregulation has also permitted the airlines, in some cases, to abandon unprofitable operations.

I think it is debatable whether noise regulations will stimulate demand for a new aircraft, but clearly they are a factor to be calculated into the overall domestic situation. New technological needs associated with deregulation, increased cost competition, and meeting noise rules will add more cost and risk to new developments; in fact, they may eliminate channels for some of the resale of used aircraft that formerly helped in providing partial financing for new equipment.

Tax incentives, the relaxation of antitrust laws to permit U.S. domestic consortiums, and other steps are being discussed as possible measures that may help industry defray development costs and apply new technology to counter foreign competition. It is not yet possible to assess the effectiveness or the final outcome of these measures.

Given that there is a role that NASA should play, I think there are a number of questions that are clearly before all of us. Should we be just the custodian of a collection of national facilities? I am referring to the wind tunnels and simulators and some of the very expensive capabilities in which the United States chose to invest and which reside for the most part under the custody of NASA. Should we limit that role to the conduct and support of only the very basic research and technology in the aero-related sciences and, in effect, step back from the interface with the more applied, risk-reduction activities that must go on in the DOD. Should we limit that activity to those technologies that are specific and generic to the civil requirements as viewed for the near future? If it is not an artificial question--and for me in some areas it becomes difficult to distinguish because of the generic nature of the technologies between military and civilian--should we, in fact, include such similar basic technologies as they are of interest to the DOD?

Should we include the applied technology programs? How far should a NASA program go toward risk reduction and meeting the needs of the various industries, both general aviation and commercial and military aviation in the United States? Or, should we in fact draw the NASA wagons in a much tighter circle around the much more basic and applied programs that I think have, in many peoples' minds, characterized the NACA aeronautics program? Should there be cost-sharing with industry and/or cost-sharing with other departments in the federal government, such as the DOD or the FAA? In cost-sharing there is a collateral question: should there be cost recoupment? This is an issue that has been debated and about which I sense there is not a consensus yet between industry and government circles regarding what role the government should play vis-à-vis the industry in risk reduction and recoupment of the cost for those investments?

Finally, I would bring up one other question, that is, the role of NASA in aeronautical research and development in the international scene. How much and what kinds of cooperation should NASA engage in with other countries and with other institutions in those countries? Since that can be viewed as a double-edged sword, there are much larger policy issues that are not the province either of NASA or of this conference relative to national foreign policy. There is, however, a set of issues that clearly falls within the purview of this group. Given that there is going to be a greater and probably more complex interrelationship between the institutions in the United States and those that exist in the other advancing and advanced nations, what should NASA's role be at that interface?

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THE LEGISLATIVE OUTLOOK

Thomas R. Harkin
Chairman, Subcommittee on
Transportation, Aviation and Communication
U.S. House of Representatives

I am sorry that I can spend only a few moments here. I would like to be here the rest of the week, compared to what is going on in Washington. I do want to thank Guy Stever for inviting me here today. It is certainly an honor to be with such a distinguished group of aeronautical leaders.

When Guy called me I said, "Well, what do you think I ought to talk about?" He said, "Well, talk about the legislative end of it--just tell them what is on your mind." So let me turn to a few comments on the legislative outlook of aeronautics or how Congress perceives NASA's role.

I guess the first point I would like to make here is that most members of Congress don't perceive the role that NASA (and before then, NACA) played in aeronautics. It may surprise you but it doesn't surprise me. Members of Congress are elected from the public at large. Very few members of the general public understand that nature of NASA's role. To most people the word "NASA" means only one thing. It is the space agency that landed men on the moon. NASA means Apollo, Saturn rockets, and moon rocks. They are usually unaware of NASA's other role and its long history of involvement with aviation. They only know about the more spectacular achievements in space.

That is the first point I would like to make--the first "A" in NASA is a well-kept secret from the general public. Now, I understand that there are some representatives here today from the auto industry. So, for their benefit as well as to further illustrate my point, I will tell you that explaining NASA's role in aeronautics has been a source of considerable frustration for me over the past 18 months.

As many of you know, I am very interested in expanding the federal efforts in automotive research and technology development. Other members of the Science and Technology Committee and I as well as some

senators, felt that the NASA approach to bringing forth new aeronautical technology could serve as a good model for this effort. I found, however, that most people, including many of my colleagues, did not understand NASA's role in aeronautics. They didn't understand the partnership nature of NASA's relationship with industry. They didn't realize that NASA tries hard to seek industry advice on research needs and priorities, and they didn't appreciate the degree to which aeronautical research projects are contracted with industry.

Rather, the typical reaction was that building automobiles was not like building a spaceship to go to the moon. They were afraid that a car built by NASA would run fine on the moon but that it wouldn't be able to take you to the corner grocery store or to work and back.

Of course, airplanes, unlike spacecraft, aren't built this way. But few people understand this distinction. It is very difficult and frustrating to explain it to them.

The second point I would make concerns the necessity for NASA to be a leader in the technical community. To their great credit this agency has long employed what I believe is the key to successful transfer of their technology to useful products. Unlike many other government agencies, NASA has a very good track record of what science people call commercialization. One need only look to the skies to see the practical results of yesterday's NASA-sponsored research.

The reason for this, it seems to me, is the close cooperation that NASA and the aviation industry have enjoyed. We see this in the operation of advisory groups. We see it in the substantial percentage of research work that is performed on a contract basis by the very companies that must eventually commercialize the results. Above all, we see this close relationsip in the overall attitude of the industry and government people involved.

As an aside, I believe that this could well serve as a model for a much needed change on our whole industry-government relationship in the United States. But, there is a hidden danger in all this harmony. This is the one that concerns us in the legislative area.

NASA has a broader constituency than just the aviation industry. In a very real way, the whole country depends on aeronautic progress: for balance of trade, for improved transportation, for safety and economy, and for national security. So, NASA must constantly look to the future. NASA's leaders must look beyond the sometimes short-range interests of their industry partners. They must strike a fine balance between research that nobody wants and that will not lead anywhere on the one extreme, and research that can be done very easily by industry on the other extreme. It is a difficult task. I know that Bob Frosch, Al Lovelace, Walt Olstad, and their associates spend a lot of time thinking about it. I just heard Bob talking about it when I came in the door. Generally speaking, I believe that NASA does a good job in this area.

Certainly NASA's record puts it head and shoulders above every other agency in Washington that is trying to advance technology. Nevertheless, it is a policy concept that NASA management must always keep fixed in their view and it is one that we in Congress intend to monitor closely.

I would mention one area that exemplifies this need for technical leadership, this need for perceiving future requirements and making sure that we are working today on the technology needed in the future. That area is advanced supersonic cruise and maneuver technology. I believe that NASA has an obligation to look beyond the concerns and limitations of today to be developing this technology for the future.

For example, it is highly likely that energy may not be our number one concern 15 years from now. It could instead be our supply of fresh water.

As a nation we are currently spending billions of dollars on energy alternatives. I firmly believe that within 10 to 15 years we may be able to say that we have gotten through the energy crunch and our preoccupation with fuel efficiency may diminish--not completely go away, but may diminish--as one of the major things to think about.

Another trend that I believe will develop is the emergence of world centers of commerce areas that are located many thousands of miles from the United States. It has to do with population, natural resources, and labor. I am thinking about such places as Brazil, with its huge land area and abundant resources; Australia, with its vast open spaces and natural resources; and even South Africa.

If this should happen, as I believe it will, the world will need high-speed transportation. If energy recedes, as I said, as the all-consuming concern, such transportation will become highly feasible. While no one is prepared to say that a market for supersonic travel is at hand today, I believe it is coming. Yes, to use a phrase that we use out in the Midwest where I am from, we are not planting enough technological seeds today to ensure a good crop when that time comes. So, I believe NASA may be shirking its responsibility for technical leadership in this area.

The present effort is, by all accounts, inadequate to provide the data base that will be needed. Most experts seem to agree that more is needed.

The Congress, for its part, appears ready to approve a reasonable program aimed at technology validation. The recent report of the Office of Technology Assessment supported this direction. As you probably know there was a House vote very recently--within the last month, I believe--on the present supersonic cruise and variable cycle engine activities. I believe this result shows a very strong underpinning of support in spite of all the emotionalism that seems to surround this issue of supersonic transports.

So now, I believe, the responsibility rests with NASA. NASA must become an advocate. No one else can do it effectively.

Now, to keep my comments in balance, I should say that there are other areas where NASA is exhibiting excellent vision, being on the cutting edge of this new technology. Their work on advanced turboprops is, I believe, a case in point. I am sure we can find many who would say that propellers will never again be acceptable for transport aircraft use. I believe they are wrong. Yet, NASA has persisted, confident that the energy advantages will ultimately prove those people wrong. I don't know how it will turn out, but I am

pleased to see that NASA is on the cutting edge of this technology.

Let me turn to another policy matter that could affect the future role of NASA in aeronautics--that is the extent of involvement in research that has traditionally fallen in the gray area between NASA and the FAA. In my subcommittee work I have had to deal with both.

I am sure it is obvious to everyone here that even the most spectacular of NASA's energy efficiency gains can be quickly nullified by air traffic delays. So, if only as a matter of self-defense, NASA should be more assertive in applying their collective systems expertise to problems of capacity in the air system.

But, there is another, even better reason. Langhorne Bond testified recently before my subcommittee that he was seriously considering limitations on air traffic growth. I feel this would be most unfortunate, especially when we have the full scientific capability of NASA available to help the FAA solve its problems, and I say that with tongue in cheek.

Therefore, I would strongly urge that NASA expand both its independent programs and its cooperation with the FAA in this vital area. I am not trying to throw rocks at the FAA, but I believe that in the recent past it has moved more toward the area of regulation and away from the area of innovation, where NASA is the strongest. This is where NASA could fill in the big gap in that gray area.

Finally, I would like to touch on a very fundamental issue, namely, where on the scale from basic research to product development should NASA's effort in aeronautics be concentrated? An easy answer would be on the whole spectrum. But, with limited resources and limited money we may have to concentrate. I know that you plan to consider this question in depth throughout the week and that is good. It is a question that needs reexamination.

My thoughts are basically this: conditions in the world are constantly changing and nothing is static. For example, I recently ran across some interesting projections from a respected financial analyst. They showed Boeing's market share dropping from 77 percent in 1978 to 64 percent in 1990, McDonnell-Douglas dropping from 15 to 8 percent, and Airbus going from 5 to 20 percent of the market. If these figures are correct, we may well be in for a proverbial, agonizing reappraisal of government's role in aviation. It is certainly clear that "business as usual" won't meet this kind of competition. Are we going to go in aviation the way of the automobile in international trade?

As a part of this reappraisal, this agonizing reappraisal, it would be logical to begin with what you are about this week, rethinking NASA's role in aeronautics. Before you do, I would suggest that your first task be to define some terms. What is meant by technology validation? What is meant by technology readiness? How far do you go before it is ready? How far do you go before it is validated? If you can all agree on that, it will be a big contribution.

Again, my own general feeling about NASA's role is that the agency has retreated too far back to basic research and away from the actual validation, away from actual, for example, flight testing with

experimental aircraft. Twenty-five years ago Dryden had a whole stable of these strange-looking flying machines. Today it is a ghost town by comparison.

We seem to have forgotten that basic research, while absolutely necessary, is not sufficient. I recognize that we must continually restock the technology shelves, and while I strongly support the R&D base programs, I also believe there is no substitute for actually making it work. It is an important question. I don't have the answer, but I can tell you that within Congress, if you are talking about money, most congressmen are willing to spend money for something tangible, something that they can put their hands on. You know that as well as I do. Guy Stever knows that from the old NSF. When you talk basic research, when you talk about things that may never have any payoff, it is a struggle year in and year out. But, when you can see tangible results, things that they can put their hands on, then you have more support. So, I just throw that out for your consideration this week when you talk about the proper role of NASA between the area of basic research and this area of commercialization and where they ought to be putting their emphasis.

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THE WORLD ECONOMIC AND FINANCIAL OUTLOOK

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Thank you, Dr. Stever. It is certainly a great pleasure for me to participate in this workshop on the role of NASA in aeronautics. I have been asked to discuss the financial and economic outlook for the aviation industry as part of the background for your discussions this week.

Before looking at the future, let us review the present status of the aviation industry. We are, unfortunately, in the middle of what probably will be the worst year in history for the U.S. airlines in terms of earnings.

Although not as hard hit as the U.S. carriers, most airlines throughout the world are anticipating a substantially lower level of earnings for 1980.

Although the depressed U.S. economy and the slowing down of economic activity worldwide are the major contributors to these events, the changed regulatory environment has also been a factor. Clearly, the passage of the Airline Deregulation Act in October 1978 has had and will have an important impact on the U.S. domestic carriers, while the philosophical underpinnings have already been widely felt on international routes. Any assessment of both domestic and worldwide industry must take into account the short- and long-term impacts of this significant legislation.

Although dedicated to the concept of less government regulation of industry, many of us in the financial community were concerned about the impact of legislation that encouraged more competition and lower fares in a future environment of steady cost increases, continuing fluctuation of traffic levels with the economic cycle, and an inability to realize the dramatic productivity gains through improved technology that were achieved in the past. We are still concerned, and recent events seem to indicate that our skepticism was well founded.

While 1978 domestic traffic was up 16 percent, the combination of higher costs and lower yields (due to the heavy use of discount fares) caused break-even load factors to rise almost as fast as passenger load factors. There is no question that the proliferation of discount fares contributed to some of the traffic growth, but there are many in the industry who believe that traffic in 1978 would have been robust without the discount fares and that, in fact, their bottom lines would have been better with less traffic growth and a higher yield.

Although the industry fared well in 1978, it is apparent that some of the seeds sown at that time have brought about the problems we are facing today. For the calendar year 1979, the U.S. trunks earned $256 million, down 76 percent from 1978. The fourth quarter was particularly devastating, with a loss of $107 million compared with earnings of $66 million for the previous year.

Clearly, 1979 was an unusual year for the industry and one we hope will not be repeated. The total increase in fuel prices from 40 cents per gallon in the first quarter to approximately 74 cents at the end of the year was staggering. Also, the United Airlines strike and the grounding of the DC-10 impacted performance. However, the high break-even load factors stimulated by the new regulatory environment heightened the industry's vulnerability to the dramatic escalation in the price of fuel.

As you are all aware, the results of the first quarter of 1980 show a further deterioration with a domestic trunk loss of $235 million compared with a $37 million profit in the first quarter of 1979. Particularly disturbing is the continued escalation of fuel costs for the U.S. carriers; at 93 cents per gallon at the end of the first quarter compared with 74 cents at year end. Total losses for the last quarter of 1979 and the first quarter of 1980 were the highest in airline history, and it appears that the domestic trunks may experience a significant operating loss for the full year 1980, the first such loss since 1961.

Losses for the second quarter may exceed $140 million. Traffic in the first half of the year was down 2.8 percent. Most carriers had hoped that there would be a substantial improvement in traffic in the third quarter that would wipe out or substantially reduce the losses of the first half of the year. However, the severity of the recession is having a devastating impact, with the prospect of far less traffic than normal for the third quarter and a very poor fourth quarter.

For the full year traffic may drop 5 to 10 percent, which would be the first year-to-year decline in two decades. During the 1974-1975 recession, traffic growth was less than 1 percent, but at least it was positive.

The situation is complicated by the fact that under the new regulatory environment we have excess capacity, and although it is now possible to raise fares to cover increased costs, particularly fuel costs, many carriers are hesitant because of the negative impact on traffic. Also, overcapacity on routes with high traffic density, such as the transcontinental routes, has created an unstable competitive environment that makes price increases difficult to implement since all carriers will not follow.

In consequence, we have very soft traffic, inadequate yields, and increasing costs, which is the formula for substantial losses and which the U.S. carriers are now experiencing and probably will experience for the balance of the year.

The regional carriers have fared somewhat better than the domestic trunks under the new regulatory environment. They have been able to drop some unprofitable routes that have been turned over to commuter carriers and enter some trunk markets, successfully utilizing traffic fed from their regional systems.

In addition, since a significant percentage of their traffic is business oriented and the trunks have not been interested in competing on the regional's relatively short route segments, their yield has been higher and less susceptible to the proliferation of discount fares.

However, even though some of these carriers have done fairly well individually, the regionals as a group report a moderate loss for the first half of 1980.

Perhaps the most sweeping impact of the present aviation policy of the Carter Administration is on the international carriers serving the United States. Even though foreign carriers are not directly affected by the Airline Deregulation Act of 1978, by means of bilateral negotiations, the Civil Aeronautics Board (CAB) is seeking to impose its philosophy of more competition and lower fares on the rest of the world. This has had the effect already of substantially diluting the yields of many international routes. On most routes throughout the world the International Air Transport Association has been able to agree on fuel-related fare increases. However, on routes to the U.S. many of these increases, until recently, were rejected by the CAB, resulting in a far greater lag in adjusting fares to cover increases in the cost of fuel on international routes serving the U.S. than on domestic routes.

This has been particularly devastating for U.S. flag carriers. Even though the international carriers serving the U.S. have more upward flexibility under the recent legislation relating to foreign routes, the policy of encouraging more competition and additional capacity on international routes serving the United States will continue to have a depressing impact on yields.

The present policy of the CAB has the effect of narrowing the profit margins of the non-U.S. carriers as well as the U.S. international carriers at a time when most governments are pushing their air carriers toward financial independence. The non-U.S. carriers are also experiencing the same scenario; i.e., a softening of traffic, increasing fuel and labor costs, and pressure on yields as indicated earlier. In consequence, the earnings performance of the carriers outside the United States in almost all geographic areas will undergo a substantial deterioration in earnings this year.

Looking ahead from the discouraging situation of the present, what do we foresee beyond 1980? Although some of the carriers are cutting back in order to more realistically match capacity with travel, others are not. Likewise, although some carriers are working toward using their new flexibility relative to fare increases to increase yield,

others are being more cautious. All carriers are working very hard to cut costs, but, unfortunately, a large percentgage of an airline's costs, particularly fuel, are really outside management's control. Some of the carriers, as they cut back, are selling or grounding some of their older aircraft. Fortunately, because of the inflationary environment, there is a market for the more efficient models of the present generation of aircraft. However, some of the less fuel-efficient aircraft have a very small market and it is anticipated that many of these aircraft will be grounded.

As we look at the present environment, those carriers with the most efficient cost and capital structure will do much better than the less efficient and more highly leveraged carriers. In fact, some of the stronger carriers are using their new route and flare flexibility to improve their market position vis-à-vis the less efficient airlines. In consequence it can be anticipated that, as we look toward the future in the new deregulated environment, some of the weaker U.S. airlines will be acquired by the stronger carriers. Not only in terms of cost structure and capital structure, but also in terms of route structures, some of the small U.S. domestic trunks will be more vulnerable with respect to survival in the anticipated future environment.

As we look at the future all indications are that the economy will improve early in 1981, which should lead to improved traffic growth by the second quarter of next year. Although this anticipated traffic growth will help pull the domestic industry out of the doldrums and improve operating performance, we have to recognize the fact that the 15 percent annual rates of traffic growth we have enjoyed in the past will probably not be with us. In addition, the cost of fuel and labor will continue to escalate, while yields will continue to be under pressure both from the political aspect of consumer pressure and as a possible deterrent to traffic growth.

In summary, the outlook for the U.S. airline industry is not all that rosy. The outlook for the non-U.S. carriers is less severe. In the first place, they have a long history, through bilateral agreements, of attempting to match capacity to anticipated traffic growth through capacity control agreements or pooling arrangements. In addition, on scheduled routes the fares are related to cost, with low-cost vacation travel relegated to charter carriers on a plane-load basis.

Although, as indicated, the profit margins of foreign airlines have been narrowed due to the U.S. policy of encouraging competition and lower fares on routes to the United States, most non-U.S. carriers operate on routes within their continent where competition is restricted and economic fares are maintained. In addition, traffic on these regional routes is more sustained over time than in the U.S., particularly now when the economies of many countries are not as depressed as that of the United States. In consequence, these carriers can often partially or wholly offset losses on routes to the U.S., whereas American international flag carriers do not have as much flexibility in this regard. In addition, when the chips are down the foreign flag carriers may well receive government support, whereas no

such support is available to the U.S. international carriers.

In consequence, the deregulation policy of the United States could hurt U.S. international carriers more than the overseas carriers. In summary, although the foreign carriers will probably have a few lean years as the recession in the U.S. spreads abroad, the regulatory environment in which they operate gives them greater ability to bridge the period to the return of traffic growth than is presently available to the U.S. airlines.

The future environment for the industry as a whole of more moderate traffic growth, higher fuel and labor costs, and pressure on yields means that there will be continued pressure on airline earnings, which can only be alleviated by productivity gains resulting from further technological improvement in aircraft design and performance.

During the past 20 years the carriers offset cost escalation by the tremendous productivity gains of jet aircraft and more recently the wide-body aircraft, as well as substantial traffic growth as air transportation reached more and more people at reasonable fares. However, in the future the cost picture will be worse. During the past 20 years, except for the last 5, fuel cost escalations were moderate, which is not the case at the present and unlikely in the future. Also, a leveling off of labor cost increases is not anticipated. As indicated, traffic growth will probably be more moderate, thereby limiting airline options in maintaining profitability through improvements in aircraft productivity or increasing of the price of their product.

If the productivity gains are not there, then the only alternative is to increase fares, which at some point adversely affects traffic and will eventually halt the steady growth of the air transportation industry and may even lead to some contraction.

The big concern of many of us involved in the air transport industry is due to the unfavorable outlook relative to operating costs, especially fuel, and the escalating cost of aircraft. The productivity gains of the new generation of aircraft--that is, the Boeing 757, the 767, and the A-310, and other contemplated advanced aircraft--could be eaten up before they are delivered in quantity in the mid-to-late 1980s.

Clearly, the productivity gains in aircraft performance contemplated for the 1980s and 1990s fall far short of those experienced in the 1960s and 1970s. This outlook represents a challenge to the aerospace industry. In the economic environment we contemplate over the next 20 years, further technological breakthroughs must be forthcoming in order to have a vibrant, worldwide air transport industry that can serve the public at a reasonable price.

As a nontechnical person looking in from the outside, the new generation of aircraft will be most helpful on top of the more up-to-date versions of the present generation of aircraft, particularly the wide bodies, such as the Boeing 747, DC-10, L-1011, and A-300. But, as we look toward the year 2000 and the economic environment that we foresee, the presently contemplated new generation

of aircraft will not be enough to ensure that we will have a viable air transport industry capable of transportating an increasing number of passengers at a reasonable cost. This can only be accomplished by a substantial investment of money and talent by both government and industry in the 1980s and 1990s, leading to substantial technological breakthroughs that will result in substantial productivity gains in aircraft performance.

Assuming that this will be accomplished, it is vital that the air transport industry have access to sufficient capital to modernize and expand its fleets with the most modern and efficient aircraft available in the 1980s and beyond. In order to access this capital it is essential that the carriers generate sufficient profits to earn an adequate return on their investments. As indicated, in an environment of continued increases in fuel and labor costs, political pressure on yields, and a lower rate of traffic growth, it is vital that the airlines operate the most cost-efficient aircraft to ensure profitable operations. Failure to achieve sufficient earnings to attract capital for fleet modernization will eventually lead to losses and financial instability as the high-cost environment accelerates the economic obsolescence of older aircraft--aircraft that the airlines cannot replace because of insufficient financial capacity.

The end result of such a scenario is less service and higher fares for the traveling public, which would in turn impede traffic growth.

The ability to generate earnings is particularly important to the domestic and international carriers in the United States that do not have access to government support. In addition, there is an increasing number of carriers throughout the world that must stand on their own feet and do not have support from their respective governments. Even in the case of government-owned or -supported airlines there has been a distinct trend in recent years toward insisting that their flag carriers attain financial viability.

Furthermore, many more government airlines must raise their funds to finance equipment purchases without government guarantees or other support, as was the case in the past. This will allow those governments to divert resources formally expended on their flag airlines to meet other pressing national needs. However, it should be noted that if the international regulatory environment does not create a climate that permits the flag carriers to realize financial independence, they will not be allowed to fail and will receive the support necessary to pursue their equipment programs from their respective governments.

In summary, then, it is clearly in everyone's interest that the airline industry maintain a sufficient degree of financial strength and stability to access capital. It might be useful at this point to review briefly where this capital comes from. For the U.S. domestic and international carriers there are three primary sources of funds: commercial banks, the long-term institutional market--primarily insurance companies and the public markets for equity-type securities. These sources are supplemented by long-term leases of aircraft.

Banks usually provide revolving credit facilities with full

availability for 2, 3, or 4 years during the period of aircraft delivery, then funding over periods ranging from 6 to 8 years with a normal door-to-door term of 10 years. The commercial banks have been the source of last resort of the U.S. airline industry during past periods of adversity and by and large have stuck with the airlines through thick and thin. However, since bank money is usually limited to a 10-year term at most, it is vital for the industry to have access to the institutional market that could offer terms of 15 to 20 years.

With the continuing escalation of the cost of aircraft, the payback period to the airline grows longer and it is most important that the financing more closely matches the useful economic life of the aircraft. In addition, due to the cyclical nature of the industry, cash-flow considerations dictate that a significant portion of a carrier's financing must have a repayment term in excess of that available from commercial banks; hence, the importance of the institutional lenders.

With the difficulties experienced by the U.S. industry in the early and mid-1970s, the institutional lenders largely closed their doors to the airlines. Fortunately, during the last several years this group of lenders has returned, but on a somewhat different basis than previously. Instead of lending on an unsecured basis for 20 or even 25 years in some cases, they have limited themselves to 15 to 18 years on a basis whereby they are secured by specific aircraft.

This takes the form of an equipment trust financing with the airline or lessor taking a 20 to 30 percent equity position on the aircraft. It is very important to the industry that this class of lenders is not scared away again.

The third source of funds is the public market for common stock, preferred stock, and subordinated debt issues. This is a vitally important ingredient because the leverage ratio--that is, the relationship of debt to equity--has an important impact on the ability of a carrier to access senior debt from institutional lendings and commercial banks. Again, during the early and mid-1970s this source was closed to the industry, but in recent years some carriers have been able to raise a modest amount of junior funds from the public market to supplement their retained earnings and reduce leverage.

As indicated earlier, a supplemental source of capital is leasing that usually utilizes banks as well as other sources for equity and institutions for long-term debt on a basis similar to an equipment trust issue. These leases usually range from 15 to 19 years. A portion of the benefits of the 10 percent investment tax credit and accelerated depreciation captured by the owner-lessor are passed onto the airline, resulting in a lower equivalent interest cost. However, since the owner-lessor is in a junior position relative to the senior lender he is particularly sensitive to the financial well being of the lessee.

In recent years, primarily as the result of competition among airframe and engine manufacturers both in the U.S. and abroad, a significant portion of both senior and junior funds have been secured by the airlines from aircraft and engine suppliers. For most of the airlines of the world other than U.S. carriers, the sources of funds

are somewhat different. However, some of the techniques developed for the American carriers, particularly those extending the term of financing to meet the useful life of the equipment, are becoming available to non-U.S. carriers. Most aircraft manufactured in the U.S. and sold abroad are financed on a basis involving a participation or guarantee on the part of the Export-Import Bank of the United States. Usually this financing involves a 10 to 20 percent down payment by the airline, which can be financed, with the balance split equally between commercial banks and the Export-Import Bank over a 10-year term with the commercial banks taking the early maturities and the Export-Import Bank the latter maturities. In the case of an Export-Import Bank guarantee, funds are raised through the Private Export Funding Corporation at market rates for U.S. government guaranteed paper, which is somewhat more expensive than the Export-Import Bank's direct lending rate.

However, due to an informal agreement between the various countries' export agencies, the Export-Import Bank's financing has been limited to 10 years from delivery, which falls considerably short of the estimated economic life of the new aircraft and today puts a substantial squeeze on cash flow. In consequence, some carriers have utilized the leasing technique or the private placement of long-term debt in order to achieve a 12- to 15-year financing instead of utilizing the Export-Import Bank's financing.

In recent years, the institutional market has opened up for a number of non-U.S. airlines, which gives them access to term funds originally available only to U.S. carriers.

In addition to the above sources of funds, some foreign carriers have secured their funds in the Eurodollar or other foreign currency markets with and without the Export-Import Bank's participation. Most such financing has been limited to a term of 10 years.

In connection with aircraft built outside the U.S., particularly the A-300, financing has been secured through the use of guarantees of the export agencies of France, Germany, and more recently the United Kingdom, to finance a very substantial portion of the aircraft. The balance has been raised unguaranteed from the commercial sources. It is hoped that the export agencies of the aircraft manufacturing countries will eventually extend their lending term to 15 years, which is more in line with the useful life of the newer aircraft.

In essence, in looking at airlines worldwide, all classes of lenders are interested in the ability of carriers to generate sufficient cash to pay back their loans over the useful life of the equipment. Also, profits ensure that a larger percentage of requirements can be met from internal cash sources, thereby limiting the amount of debt required. Lenders also want to see a sound capital structure with moderate leverage to gain confidence that the airline can ride through the normal economic cycles that historically have affected airline traffic and earnings.

In conclusion, the same sources of capital utilized in the past will be available in the 1980s and beyond to assist the airlines in modernizing their fleets as long as they can demonstrate sufficient earnings and cash flow to meet their obligations. However, in our

view this will only be possible if the aviation industry has at its disposal cost-efficient aircraft that will permit them to operate profitably in the anticipated economic environment where costs will be higher, fares tailored to the ability of the public to pay, and traffic growth less robust than in the past.

I hope that your deliberations this week will bring us closer to that goal. Thank you very much.

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THE OUTLOOK FOR PETROLEUM

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I have been asked to discuss the outlook for petroleum, and I would like to begin by addressing the question of how much more expensive petroleum is going to get. I refer to Figure 1. This is a figure that appears every year in an Exxon publication, and it is Exxon's estimate as to what the world's oil picture is going to look like in terms of oil reserves and production. It is interesting to watch this year by year because the picture is becoming progressively more pessimistic. A year ago the curve went up more steeply for production, indicating that people thought they were going to be using more oil than they are; but more importantly, the future discoveries estimate also was higher so that it actually was a little bit above production. This year it is less than productive.

These are five-year averages of future discoveries. If future discovery rates are less than production roles, reserves are going to be drawn down. The reserve drawdown is the underlying factor that is going to determine price and supply. This changes every year, so any one set of such curves should not be taken too seriously. However, a very informed group of people feel that, despite reduced consumption of petroleum due to the price situation in the world, the future discovery rate is not going to be able to keep up. So, the people who have oil are likely to charge more for it. If this is, indeed, the picture, then oil is going to become more expensive. The kinds of numbers I have heard people quote--and they can't be taken too seriously--are a factor of two or three times the current price in 1980 dollars for the end of this century. That would be based on a situation whereby an increasingly scarce but needed commodity is being sold. Maybe we will be lucky and it will turn out differently.

One way to look at the tightening petroleum situation is shown in Figure 2. I want to look a little farther into the future than the

time frame we are talking about here because I feel that, since our effort is to guide the research activity in aeronautics, we ought to be considering the period of maybe 2020-2030 as a target time--certainly not just the next 10 years because unconventional oil sources are not going to have much impact then.

This particular set of curves is convenient to use. It appeared in Science magazine and was based on a large international study. These curves show more growth than is indicated in Figure 1. The slope of the total oil demand curve is higher, and the estimates in the two figures do not correspond very well. But, this figure does give an integrated view of where the oil is going to come from. Although the Middle East has large reserves, they are being drawn down quite rapidly. Conventional oil reserves are projected to be severely depleted by 2030. Unconventional oil, which includes enhanced recovery, heavy crudes and oil shale, will help to make up the difference, with coal liquefaction not really coming in until around the turn of the century.

If we are concerned about aircraft fuels in the period beyond about 1995, we are going to be looking at an increasing variety of sources. In the period beyond 2000, oil from the new reserves probably isn't going to be much cheaper than oil produced from the unconventional sources because it will be so difficult to find and produce.

One must state the framework of a discussion of this nature. Figure 3 shows that I am really looking way out in the future and am not trying to cope with the next 10 years. This view of the world's energy growth indicates that it is not going to be very rapid and probably not as rapid as the international study indicated. Worse than that, it is going to be erratic, in my opinion. We will probably have a series of crises. We will have times of real shortages and times like the present when the consumption has gone down a little bit below production and inventories are building up. So, it is going to be a very erratic situation; that is the pessimistic part.

The encouraging part is that these problems are becoming increasingly obvious, and we are going to see a major effort in this country to convert solid resources into liquids. Our resources are solids, such as coal, shale, peat, and so on, and we will need new sources of liquids for the uses we anticipate. In addition, there is a major effort to conserve liquid fuels by improved technology and practices. This is the framework that I use in this discussion.

A little bit of optimism on synthetic fuels is shown in Figure 4. What has happened during this last year is almost like a religious conversion in some of the major energy companies. There has been a rather sudden recognition that synthetic fuels offer a major opportunity. A year or two ago it was not like that, although there were groups in the oil companies that were pushing synthetic fuels.

We now have major energy companies proposing very large synthetic fuel developments as something that the nation should have. I think they are correct in this case. In addition to that, companies that really haven't been in energy--chemical companies and the like--are developing the plans for synthetic fuels. The new synthetic fuels

corporation, just getting under way, makes it possible for the companies that haven't been in energy to consider really major projects, with financial backing available from the U.S. government.

One position of the major energy companies is that, for the part they would play, they don't really need that backing. This varies from day to day, but generally this is the case. The federal goal is 2 million barrels a day by 1992, with the hope of getting up to 6 or 8 million barrels a day by 2000, or roughly up to the present liquid fuel import rate.

Synthetic fuels, it must be remembered, are not all liquids. Some are gas.

What I include is the conversion of solids into either gas or liquids, although it could be broader. One might ask about tar sands. When they are dug up they are solids. Fundamentally, that is the problem. We have solid sources of energy, and we really want fluid sources.

The reason for this sudden switch on the part of the energy companies and also nonenergy companies is that, at present world prices, it appears that some of the approaches would be good investments, assuming the current price structure projections.

An Exxon proposal is shown in Figure 5 that indicates a production goal for synthetic fuels going up to as much as 15 million barrels a day by 2010. They didn't choose the same time period as the federal government so there is a little ambiguity. While this estimate was based on supply and demand projections, it really boils down to a judgment on how fast the industry could be built up if we really tried.

This proposal does stretch our national capabilities. It calls for an investment of about $800 billion, 1980 dollars, for mining and production. This would employ almost a million people, including some very special kinds of people. Almost 500,000 of these people would be in mining, which is about 60 percent over the total in mining now. The number of people needed to run the process plants would be up about 55 percent, and design engineers would be up 35 percent over present levels. It certainly offers a major employment opportunity and will require a major training program.

This is a very interesting study because it is, again, integrated. If we want to really do something about energy, this is what one group thinks could be done in the next 30 years.

Where would this energy come from? As shown in Figure 6, shale is the big source. We have two kinds of shale operations, all out in Colorado and Utah; about 6 million barrels a day from surface mines and 2 million from underground mines have been proposed.

If there is an interest in doing something really significant in terms of shale oil production, surface mining emerges as the way to go. It has probably less environmental impact, and it gives much higher overall resource recovery--in the range of 70 to 80 percent versus on the order of 15 to 20 percent for mining. Surface mining employs fewer people for the amount of oil that is produced, which is looked on as an advantage in Colorado because the impact of such a huge industry is of real concern.

As for coal, much of it is in western regions, particularly the

Powder River Basin. Quite a bit of eastern coal, largely lignite, is in the Gulf and the Texas-Arkansas areas. In the time period we are talking about, mostly gas would be produced from coal. Overall production would be about half liquids and half gas in the example shown. It should be recognized that production of gas in effect displaces liquids and can therefore reduce petroleum.

Figure 7 considers the cost of synthetic fuels. Absolute cost in these areas is a very slippery sort of thing, so I have taken the coward's way out and used cost ratios. Shale oil was used as the standard since it is believed to be the cheapest synthetic liquid. Its cost is considered to be about the same or less than the current price of imported petroleum.

Intermediate BTU gas, which is a carbon monoxide-hydrogen mixture, will be extremely important industrially and costs about the same as making liquid from shale. It would be manufactured from coal, and pipelined or shipped by rail into industrial areas.

For high BTU gas (methane) the cost goes up to 15 to 25 percent over liquids from shale. Methanol is slightly higher and is the lowest cost coal-base liquid. Methanol promises to be an important fuel, but not for aviation.

The cost of refined coal liquids is high. There is some hope that with more research and improved technology the cost will go down. That is why the international study I referred to didn't show coal liquids becoming very important in the near and mid-term.

Let us look at the situation in other countries. As shown in Figure 8, the U.S. is fortunate. We have some major resources of almost everything except tar sands. Canada has good resources. They don't have much in the way of good-quality shale, but their tar sands produce oil at about the same cost as shale, so they are in about the same shape as the U.S. North America, then, is in pretty good shape as far as liquid fuel sources.

Europe has limited supplies of the fuel sources mentioned. They can help themselves quite a bit by working with those but must rely as well on imports. Japan also must rely on imports.

One of the points to recognize is that the fuel situation is going to be very different in different parts of the world. The dynamics of supply and manufacturing are going to be different, and the composition of the fuel could well be different. Predicted trends are shown in Figure 9. I really want to emphasize the probable increasing frequency of shortages. When shortages occur the specialty fuels--and jet fuels are classed as a specialty fuel because of their very restrictive specifications--immediately get very tight in supply. This has happened during the last two shortages.

We are also going to have a shifting mix of projects in addition to the shifting raw material sources.

Some projections trends are shown in Figure 10. In the industrial sector, the liquid fuel demand will be going down, even though the projections this is based on showed continued industrial growth in this country. Liquid fuel use has in fact been growing in industry as imported fuels were used to displace gas; however, that trend will be reversed as gas supplies improve.

The nonenergy (petrochemicals, etc.) commercial and residential consumption will actually decrease somewhat due to increased use of gas and electricity.

The total transportation demand will stay about the same; if the two transportation categories are combined they total 9.9 million barrels per day in the first case, and 10 in the second. The auto and light truck demand, of course, is the one that is going down in a spectacular manner as the public insists on smaller automobiles and better mileage. However, the use of aircraft for transportation will grow and the use of diesel fuel will also grow for truck transportation and the like. The transportation demand overall therefore becomes an increasing fraction of the total; however, the total has gone down slightly for the year 2000 and will continue to decrease as nonliquid energy sources are substituted.

As an example of substitution, consider the electric power that is distributed in these consuming sectors. The liquid fuel demand is expected to go down from 1.4 to 0.3 million barrels per day as we back away from the use of imported fuel.

These changes in demand for U.S. petroleum products will have a very large effect on the operation of an oil refinery. One way to characterize an oil refinery is by the gasoline-to-distillate ratio (Figure 11). Distillate includes mostly jet fuel, home heating oil, and diesel fuel. Historically, the ratio of gasoline to distillate has been about 1.7. American refineries have worked hard to make more gasoline and less distillate and have developed many processes for this purpose.

We have considered two cases for the year 2000, one in which the use of the diesel automobile experiences only slight growth; the other case projects the higher rate of growth that is forecasted by the automobile industry. In the latter case, the ratio decreases to 0.7 versus 1.7, which means, in effect, that the refineries would be working hard to make more distillates.

This is an important change because when distillate quantity increases quality tends to decrease.

There are some implications in this for aviation. It is clear that the competition for quality distillate fractions is going to increase because the automotive diesel system will work better on a fuel of higher quality than on the present diesel fuel. For example, a better quality fuel will improve starting in winter and facilitate handling of emissions problems.

Since the distillates represent a larger fraction of the total, the lower-quality cracked stocks will have to be used in larger proportion. It has been the practice to try to minimize cracked products in better-quality fuels such as jet fuel. Poor-quality fuels can be upgraded by hydrogenation; however, with increased cost and increased manufacturing energy consumption, special facilities would have to be justified and constructed and some flexibility in dealing with sudden changes in crude supply and composition would be lost.

There are going to be supply disruptions and when that happens the product quality will tend to go down because it is very difficult to make high-quality, special products while maintaining supplies of the

major commodity fuels. As a nonaviation person, I am led to believe that the best position to be in would be to have aircraft that are capable of using a fairly wide range of fuels. One may not want to use the lower grades all the time or even as a standard, but there will be times when maybe that is all one can get.

The question, then, is what can be done to extend the capability of aircraft to use a variety of fuels. Let us consider how jet fuel characteristics relate to performance and availability.

The flash point is the temperature at which the vapor-air mixture above the fuel becomes flammable. At the present time this is set at around 100°F. Figure 12 presents estimates that were developed for an ASTM committee grappling with the question of whether the flash point could be reduced a little more. Reducing the flash point does make available substantially increased quantities of components. It doesn't guarantee that they will be available for jet fuel, but it does allow a lot more flexibility. If the flash point is reduced to 80°F, it allows a 22 to 30 percent increase in useable components. These are the fractions in the 80° to 100°F range that would otherwise be processed to go into gasoline. Use of these fractions would not interfere directly with diesel fuel production since diesel fuel has a higher flash point. Using more low boiling material allows use of more high boiling material while still meeting freezing point requirements. Flexibility is significantly increased.

The question is one of safety. Certainly many areas experience termperatures greater than 80°F. Fuel flash point is a question that I think needs to be addressed because it is the easiest way to increase jet fuel supply flexibility.

Another important characteristic of jet fuel is freezing point (Figure 13). Increasing the freezing point makes a big difference in the stocks that are available for jet fuel. Jet A-1, a European specification, has been practical because Europe had the stocks to meet this specification fairly easily. With Jet A-1 as a base with a -50°C freezing point, a comparison with Jet A, which has a -40°C freezing point, shows a 45 percent increase in suitable components for Jet A. If the freezing point were set at -35°C, the increase in components would go up to 70 percent. Freezing point is a requirement that has a lot of leverage. Here, again, there are reasons for wanting it low. Freezing point requirements should be examined very carefully, and I believe it would be desirable to have the capability to use jet fuels with higher freezing points.

Aromatics or hydrogen content is another important factor to be considered in jet fuel specifications (Figure 14). As distillate demand increases and more low-hydrogen-content refinery feeds such as tars are used, more and more cracked stocks will go into the distillate pools. As an example, Jet A fuel in the past has had 20 percent or less aromatic content. Some of the recent restrictions on crudes and refineries are leading to prediction of jet fuels with 25 percent aromatics. The distillate fuels derived from cracked stocks after treatment to improve stability and so on have an aromatics content in the 30 to 40 percent range. There will be continued pressure to use these cracked stocks. In the past, cracked solids

have been sold as domestic heating oil and diesel fuel.

Something can be done about it. Hydrogen can be added to reduce aromatics, but this is expensive. Hydrogenation wastes energy and requires long-term planning and special equipment, particularly if the hydrogen must be made from coal. This could be done, but it will increase the cost of air travel.

As I noted earlier, the other major distillate fuels will contain 30 to 40 percent aromatics. The thing that is intriguing is that combustion systems can be built that will run satisfactorily on higher aromatic fuels. But there are some trade-offs, and there have to be plans to do it. So, here again is an opportunity to increase the flexibility of aircraft that should be considered.

The last important jet fuel property is thermal stability (Figure 15). In current aircraft, particularly high-performance aircraft, there is a tendency to use the fuel as a dumping ground for heat. This causes deposits and a variety of other problems. Current stability requirements limit the refinery streams that can be used in jet fuel. Even mildly hydrogenated cracked stocks tend to go over the edge on jet fuel stability. In fact, about the only products that meet jet fuel stability requirements are the straight-run distillates that have been very carefully treated.

As more cracked and high boiling stocks are put into jet fuel, even if they are partly hydrogenated, the stability problem arises. Therefore, one of the things that would really help on jet fuel supply flexibility would be for the new generations of aircraft to have less fuel stability requirements.

What are the trade-offs and what are some of the things being done about the problem? Industry and government are working, through the American Society for Testing Materials, on jet fuel specifications and testing programs. I have mentioned the increases in aromatics that are being discussed. They are looking carefully at the flash point question, which I sensed is going to require more research.

Of special importance to this meeting is the fact that NASA has initiated a major program to acquire the necessary data to reoptimize the aircraft fuel interface. It would be very difficult to make the case that a fuel composition based on past availability of relatively inexpensive petroleum is optimum for the future. What the future material should be isn't known. It could be higher quality for some uses, such as supersonic flight; it could be lower quality for other uses. The answer is not clear.

NASA is not going to develop fuel specifications. The purpose of their work is to develop a data base to allow others to work the optimization problem and to match the requirements of the aircraft to fuel supply as time goes on.

The Department of Defense has a substantial program largely related to assessing how well military aircraft can operate with the newer fuels and with the present equipment.

AGARD and the NATO people are beginning to work on the problem on an international basis; they will participate with NASA in refinery simulations and will think the problem through themselves. As usual, there are quite a few viewpoints, but there is real interest in

working at the problem.

One thing NASA did was decide that, if there was going to be a broad look at this problem, there should be an experimental fuel that could be used by all participants as a standard point of departure. The characteristics of this experimental fuel are shown in Figure 16. The aromatics content has been increased to match more closely the components that would be available from cracked stocks and synthetic fuels. There is no change in flash point.

A substantial change was made in the freezing point. This change could make quite a difference in the supply picture. It was made on the basis that the higher freezing point would probably be satisfactory for about 98 percent of the flights. It was recognized that there would be some exceptions, such as very long, high-altitude flights or perhaps cold weather operations in Alaska.

There is very little change in the stability temperature limits. The experimental temperature was set slightly lower, and it indicates what the experts thought might be done with very careful treatment of the higher aromatic fuel. This limit, however, falls short of providing for interchangeability with diesel fuel, for example. This fuel has been acquired. It is being worked with and used as a baseline fuel.

There are some general conclusions that can be drawn from all of this (Figure 17). First, refining technology is capable of producing high-quality jet fuels from future stocks, and if we hae a steady, well-planned world there is no reason why we need to have poorer materials. But this doesn't mean that we should keep going just the way we are. I don't believe we can be assured of a well-planned, orderly future.

To even maintain the present jet fuel specifications or to go to better ones will require a considerable amount of new, specialized equipment installed on a worldwide basis. The difficulty of meeting these specifications is going to vary considerably around the world. Some countries will be in relatively good shape and others will not.

I believe that if the newer aircraft could accept a wider range of fuel properties we would be better off in the future than if we continue to be restrictive or become more so as far as jet fuel is concerned. The question is what it costs in terms of performance operating problems and capital investment balanced against the fuel costs. We don't have the answers now, and we need a substantial program to get the information to solve the problem.

We should have the philosophy of developing, what I would consider, rugged types of equipment that can tolerate conditions that aren't quite ideal. The omnivorous airplane is probably too much to hope for, but I think we should be able to work out an optimum compromise.

The message is that we really ought to look at fuel quality as a variable and build that into the advanced programs.

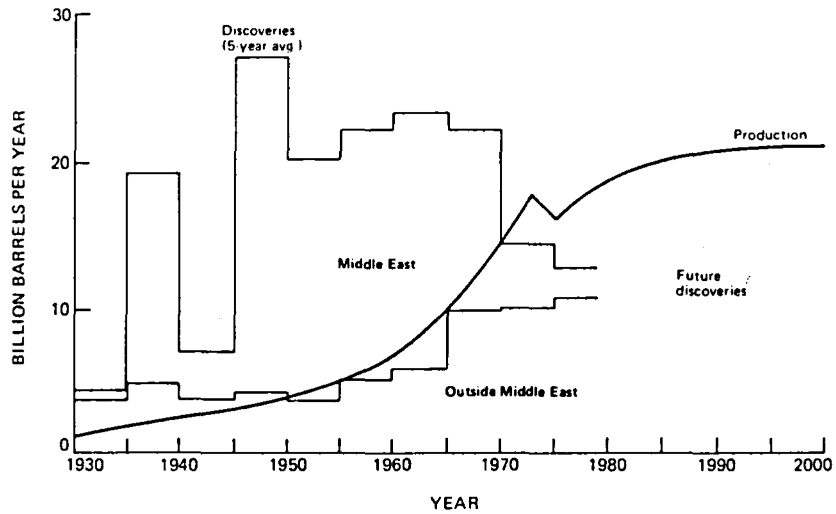

FIGURE 1 World oil discovery and production rates from 1930 to 2000, excluding the People's Republic of China, the Soviet Union, and Eastern Europe (Exxon, 1980)

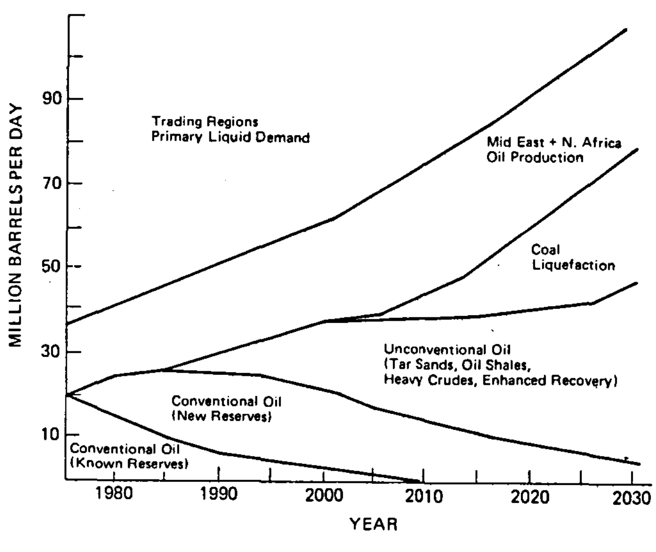

FIGURE 2 Oil supply demand 1975 to 2030 for the world, excluding centrally planned economics

FRAMEWORK FOR THIS TALK

Time Frame:	1990 - 2030
World Energy Growth:	Low and Erratic Due to a Series of Crises
U.S. Response:	A Major Effort to Convert Solid Resources to Liquids
	A Major Effort to Conserve Liquid Fuels

FIGURE 3

SYNTHETIC FUELS

Supply Instability and Price Increases Have Resulted in a Clear Economic Driving Force.

- Major Energy Companies are Proposing Major Developments
- Former Non-Energy Companies Developing Plans Stimulated by the U.S. Synthetic Fuels Corporation
- Federal Goal is 2MB/D (Oil Equivalent) by 1992

FIGURE 4

ONE PROPOSAL FOR A MAJOR SYNTHETIC FUELS INDUSTRY

Production Goal:	15 MB/D by 2010
Investment for Mining and Production:	800×10^9 (1980 Dollars)
Employment:	870,000 People

FIGURE 5

PROPOSED SOURCES OF SYNTHETIC FUELS

		MB/D
From Shale		
	Surface Mines	6.0
	Underground Mines	2.0
From Coal		
	Powder River Basin	3.0
	Other Western	1.1
	Eastern	2.7
	Gulf	0.2
	Total	15.0

FIGURE 6

COST OF SYNTHETIC FUELS

	% Increase in Cost Over Shale Oil
Shale Oil	0
Intermediate BTU Gas	0
Methane	15-25
Methanol	20-30
Refined Coal Liquids	40-60

FIGURE 7

GEOGRAPHICAL DIVERSITY OF LIQUID FUEL SOURCES

U.S.	Petroleum, Tar, Shale, Coal, Peat, Biomass
Canada	Petroleum, Tar, Coal, Peat, Biomass
W. Europe	Petroleum, Coal, Peat, Biomass
Japan	Primary Reliance on Imports

FIGURE 8

PREDICTED TRENDS

- Increasing Frequency of Shortages
- Recurring Tight Supply of Specialty Fuels
- Shifting Product Mix
- Shifting and Varied Raw Material Mix

FIGURE 9

DYNAMICS OF LIQUID FUEL USE

United States

DEMAND MB/D

Consuming Sector	1980	2000	Major Trends
Industrial	2.8	2.2	Current Growth Reversed
Non Energy Plus Commercial/Residential	5.1	4.2	Decrease Due to Gas and Electricity Substitution
Transportation Auto plus L. Truck	7.1	4.5	Will Become an Increasing Fraction of the Total
Other Transportation	2.8	5.5	
Total	17.8	16.4	Continued Decrease
Electric Power	1.4	0.3	Elimination of Heavy Fuel Oil Use

FIGURE 10

U.S. PETROLEUM PRODUCTS DISTRIBUTION

Year	Gasoline/Distillate Ratio	
	Min. Diesel Growth	Max. Diesel Growth
1975	1.7	1.7
1980	1.5	
1990	1.2	
2000	1.0	0.7

FIGURE 11

FLASH POINT

- Decreasing Flash Point is an Effective Means of Increasing the Range of Refinery Stocks Suitable for Jet Fuel

Flash Point ^oC (^oF)	% Increase in Suitable Components
38 (100)	Base
32 (90)	10-18
27 (80)	22-30

- Takes Advantage of Future Reduced Gasoline Consumption
- Minimum Interference with Diesel Fuel Production
- Makes Possible Addition of Higher Boiling Components

FIGURE 12

FREEZING POINT

- Increasing Freezing Point Greatly Increases Refinery Stocks Suitable for Jet Fuel

Fuel	Freezing Point °C	% Increase in Suitable Components
Jet A-1	-50	Base
Jet A	-40	45
--	-35	70

- The Same Higher Boiling Fractions are Useful for Diesel and Heating Oil
- The Higher Boiling Fractions Tend to Increase Liner Heating and Smoke

FIGURE 13

HYDROGEN CONTENT (AROMATICS)

Increased Distillate Demand and Low Hydrogen Content Refinery Fuel Will Result in Increased Use of Cracked Stocks in Distillate Products

	% Aromatics
Jet A	20
Revised Jet A	22/25
Distillate Fuels from Cracked Stocks	30-40

- Hydrogenation will Reduce Aromatics But is Expensive, Wasteful of Energy and Requires Special Equipment
- Other Major Distillate Fuels Will Contain 30-40% Aromatics
- Properly Designed Combustion Systems Can Satisfactorily Burn High Aromatic Fuels.

FIGURE 14

STABILITY

- Stability Requirements Limit Refinery Streams That Can Be Included in Jet Fuel
- Other Distillate Products Do Not Meet Jet Fuel Stability Requirements
- Cracked and High Boiling Stocks Increase The Stability Problem
- Aircraft With Less Severe Stability Requirements Would Greatly Increase Future Fuel Options

FIGURE 15

EXPERIMENTAL BROAD SPECIFICATIONS FUEL

	Jet A	Experimental Fuel
Hydrogen Wt Percent	~ 14	~ 13
Aromatics Vol Percent	< 25	~ 35
Flash Point ^{o}C	> 40	> 40
Freezing Point ^{o}C	-40	-29
Break Point Temp ^{o}C	> 260	> 240

FIGURE 16

GENERAL CONCLUSIONS

- Refining Technology is Capable of Producing High Quality Jet Fuels from Future Fuel Stocks

- This Will Require Increased Use of Specialized Equipment as Feed Stock Quality Decreases and Competition for Distillate Fuel Increases

- The Difficulty of Meeting Specifications Will Vary Greatly with Location Especially in Times of Crisis Fuel Shortages

- Aircraft Capable of Accepting a Substantially Wider Range of Fuel Properties Appear to Fit the Future Better than Aircraft with Restrictive Fuel Requirements

- A Substantial Program is Needed to Acquire the Information Needed for Future Aircraft/Fuel Optimization.

FIGURE 17

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PERSPECTIVE ON ENGINEERING MANPOWER

Patrick J. Sheridan
Manager, Manpower Activities
American Association of Engineering Societies

I would like to thank Dr. Stever and the Aeronautics and Space Engineering Board of the National Research Council for the opportunity to speak at your workshop this afternoon. Perhaps it might be well for me to take a moment to say a few words about the American Association of Engineering Societies, the parent organization of the Engineering Manpower Commission.

AAES, as it is now known in the alphabetical jargon of engineering societies, came into existence in December 1979. It has a membership of some 38 engineering societies with a membership of more than 650,000 professional engineers. Its predecessor organization was the Engineers Joint Council.

AAES is made up of four councils. They are known as the Educational Affairs Council, the International Affairs Council, the Public Affairs Council, and the Engineering Affairs Council.

The Educational Affairs Council is concerned with such things as guidance for young people who are interested in studying engineering, continuing education for experienced engineers, engineering and technical education, and maintaining liaison between the engineering societies and the Accreditation Board for Engineering and Technology (ABET).

The International Affairs Council is concerned with the coordination and communication of international activities and works with groups such as the Pan American Federation of Engineering Societies, the World Federation of Engineering Organizations, the World Energy Conference, and the U.S. Committee on Large Dams.

The Public Affairs Council is concerned with establishing a Washington presence on behalf of its member societies. It is also responsible for developing engineering information relevant to current public issues. The coordinating committee on energy is part of the Public Affairs Council.

The Engineering Affairs Council through the Engineering Manpower Commission is concerned with the adequacy of engineering manpower to meet national goals. The Engineering Manpower Commission through survey programs furnishes information on education, placement, demand, and compensation of engineers and technologists. The Engineering Affairs Council is also responsible for maintaining and publishing the guidelines to professional employment for engineers and scientists. The Engineering Practices Information Center (EPIC) is part of the Engineering Affairs Council. EPIC monitors legislation affecting engineering in every state of the United States and alerts subscribers with pertinent information concerning this legislation. The Engineering Affairs Council is also responsible for publishing Who's Who in Engineering. This publication is revised every two years and consists of a listing of engineers who have distinguished themselves by their contribution to engineering technology.

I would now like to discuss with you some of the studies conducted by the Engineering Manpower Commission and then review some of our most recent findings.

Each year after the September enrollment, the Engineering Manpower Commission conducts a survey of the engineering and technology schools in the United States to determine the level of enrollment and the engineering and technology disciplines in which the new students have enrolled. These data are further broken down by women and minority students. The data are presented by schools on the basis of graduate and undergraduate programs. Accreditation data by program are also presented. In June of each year we do a survey of the same schools to determine the number of graduates and the programs from which they graduated. The breakdown is similar to that of the enrollment survey and is presented on the basis of school, by women and minority, and by curriculum. Every two years the Engineering Manpower Commission conducts a salary survey of professional engineers. This includes all engineers in industry, education, and government with a four-year degree in engineering. The data are presented on the basis of maturity--years since B.S. degree--and are further broken down by supervisory status and degree level, such as bachelors, masters, or Ph.D.s. Groupings are also presented on the basis of industry type; state, local, and federal government; and by academically employed engineers on the basis of 9- or 12-month contracts.

The Engineering Manpower Commission has, over the years, published manpower bulletins summarizing the results of its various surveys and presenting other items of information to the engineering community. These are distributed on a subscription basis to engineers and engineering employers who are interested.

I would now like to review with you some manpower history based on the studies taken over the years by the Engineering Manpower Commission. We will also look at the latest manpower information available, which in most cases is that from the 1979 studies. We are now in the process of collecting data for 1980, but this information will not be available until sometime in October. The data that you are about to see, for the most part, are general information covering

all engineering disciplines. Where possible we have isolated aerospace engineering to give you a specific feel of how this relates to the overall engineering picture.

Figure 1 shows total engineering undergraduate enrollment. In 1979 this amounted to some 340,488 undergraduate students enrolled in 280 schools that award a bachelors or higher degree in engineering. This represents a 9 percent increase over those enrolled in 1978 and an 82 percent increase over those enrolled in 1973. Both women and minorities increased 21 percent over 1978 enrollments. Comparing this with the overall increase in enrollments of 9 percent indicates that women and minorities are now getting a greater share of engineering enrollments. Of the 340,488 enrollments, 9656 students were enrolled in aerospace engineering programs. This represents a 21 percent increase over 1978, when the aerospace enrollment was 7949 students. So, we might say that things are looking up in aerospace engineering enrollment. Of the 9656 students enrolled in aerospace engineering programs, 435 (4.5 percent) are foreign national students here on a temporary visa.

Figure 2 shows a breakdown of engineering enrollment on the basis of freshmen, sophomores, juniors, and seniors. I have also shown graduate students in Figure 2, which were not included in the total in Figure 1.

Freshmen enrollment in 1979 was 103,724. This represents an 8 percent increase over 1978 and a 100 percent increase over 1973. Sophomore enrollment of 78,594 represents a 9 percent increase over 1978, and junior enrollment at 74,928 represents a 7 percent increase over 1978. Senior enrollment at 83,242 represents a 13 percent increase over 1978. Retention rates from 1978 and 1979 showed that 82 percent of all freshmen became sophomores, 119 percent of the juniors became seniors, and 72 percent of the seniors graduated with a B.S. degree in engineering. Retention rates greater than 100 percent are due to transfers into engineering programs from other disciplines. As we all know, there is a great deal of transition in and out of engineering curricula. There is always a heavy loss from the freshman class to the sophomore class. This is made up, to some extent, by students enrolled in other scientific fields who decide to transfer to engineering at the end of their sophomore and junior years. Not all of them make it, however, since only 72 percent of the seniors eventually wind up with a B.S. degree in engineering.

Graduate students increased 8 percent over 1979 to 41,384 enrollments. Thirty-four percent of the graduate enrollments in engineering curriculum are made up of foreign national students. Thirty-one percent of the masters degree candidates and 39 percent of the doctoral candidates are foreign national students. With respect to aerospace engineering, some 31 percent of the candidates are foreign nationals and 51 percent of the Ph.D. candidates are foreign national students. The number of women in graduate programs increased 16 percent over 1978.

Figure 3 shows that engineering degrees awarded in 1979 amounted to 52,598 at the bachelor level. This represented a 14 percent increase over 1978 and a 21 percent increase over the number of

degrees awarded in 1973. Of this total, 9 percent were awarded to women, as contrasted with 1.4 percent in 1973. Two percent were awarded to Blacks, as contrasted with 1.5 percent in 1973. One and one-half percent went to Hispanics, as contrasted with 1.3 percent in 1973. Asian Pacifics were awarded 3 percent of the engineering degrees in 1979 and 1.6 percent in 1973. American Indians made up about 0.1 of 1 percent in each of those years. Comparing the makeup of the 52,598 degrees awarded in 1979 with the number of degrees awarded in 1978, women were up 44 percent, Blacks were up 20 percent, Hispanics were up 10.1 percent, Asian Pacifics were up 28.2 percent, and American Indians were up 59 percent. Compared with the overall increase of 14 percent, women and most minorities made headway over 1978.

Masters degrees in engineering were down 1 percent from those granted in 1978. The 16,036 master degrees awarded in 1979 were also 6.5 percent less than those awarded in 1973. Twenty-five percent of the masters degrees awarded went to foreign nationals in 1979. At the masters level, women increased their participation by 9.3 percent. Minorities were down. Blacks were off 21 percent, Hispanics were down 12 percent, and Asian Pacifics were down more than 14 percent.

The number of doctoral degrees awarded in 1979 was 9 percent greater than in 1978. However, the 2815 doctoral degrees awarded in 1979 was 22 percent below the number awarded in 1973. Thirty-three percent of the doctoral degrees were awarded to foreign nationals. Two percent of the Ph.D. degrees went to women, 0.7 percent went to Blacks, and 0.8 percent went to Hispanics. Six percent of the doctoral degrees went to Asian Pacifics.

Taking a look at aerospace engineering degrees shown in Figure 4, we find that in 1979 there were 1145 degrees awarded. Although this represents a 17 percent increase over the number of aerospace engineering degrees awarded in 1978, it represents only 86 percent of the total number of degrees awarded in 1973. At the masters degree level, the 381 degrees awarded in aerospace engineering in 1979 is 93 percent of the number of degrees awarded in 1978 and 62 percent of the number of master degrees in aerospace awarded in 1973. Ph.D. degrees also dipped in 1979 to 82 percent of those awarded in 1978 and about half of those awarded in 1073. Foreign nationals received 26 percent of the masters and 50 percent of the doctoral degrees awarded to aerospace graduates.

Figure 5 translates the numbers in Figure 4 into percentages to reflect participation of aerospace in engineering curriculum. We find that bachelors degrees in aerospace engineering amount to 2.2 percent of the total awarded, masters degrees about 2.4 percent of the total awarded, and Ph.D. degrees about 3.3 percent of the doctoral degrees awarded. In each case, you can see there is a substantial decrease from the heyday of 1972.

Figure 6 compares the degrees awarded to women to the freshman enrollment in all engineering curriculum. Women represented 14 percent of the total freshman enrollment in 1979. This was 19 percent over that of 1978 and 480 percent over that of 1973. Nine percent of the total degrees awarded in 1979 went to women. This was a 44

percent increase over 1978 and a 650 percent over 1973. Forty-seven percent of the degrees awarded to women were in three major fields: mechanical engineering--13 percent, electrical--13 percent, and chemical--21 percent.

Figure 7 shows that Blacks made up 6 percent of the total freshman enrollment in engineering. Their total enrollment of 6339 represented a 15 percent increase over 1978 and a 197 percent increase over 1973, which indicates good progress but it does not quite come up to the progress made by women. With respect to degrees awarded, Blacks received 2 percent of the total. Sixty-three percent of the degrees awarded to Blacks were in the fields of mechanical--21 percent, electrical--32 percent, and chemical--10 percent.

Figure 8 shows that Hispanics made up 3 percent of the total freshman enrollment in 1979. This represents an 18 percent increase over 1978 and a 29 percent over 1973. Degrees awarded to Hispanics amounted to 1.5 percent of the total degrees awarded. Forty-seven percent were in two fields: mechanical--19 percent and electrical--28 percent.

Figure 9 shows the participation of women and minorities in the degrees awarded for aerospace engineering. Although some slight gains have been made by Blacks and Hispanics, women have penetrated the aerospace field considerably, increasing their participation in terms of degrees awarded by some 350 percent since 1974.

Figure 10 shows some changes that have taken place in the participation of students in selected engineering curriculums over the past decade. In 1969 some 28.5 percent of the degrees awarded were in the electrical engineering field. This fell to 23.2 percent in 1979. Over the same period, mechanical engineering dropped from 21.1 percent to 19.2 percent. On the other hand, civil engineering went from 14.9 percent in 1969 to 19.1 percent in 1979. Chemical engineering over the same period went from 8.6 percent to 11.1 percent, and aerospace dropped from 5.5 percent of the total degrees awarded in 1969 to 2.2 percent of the total degrees awarded in 1979.

Figure 11 shows the status of engineering graduates as of their date of graduation. Our 1979 survey showed that 76 percent were employed as of their date of graduation, 12 percent were entering graduate studies, and 3 percent had no offers or plans. In my opionion, the key items in this analysis are (1) entering graduate studies, (2) considering job offers, and (3) no offers or plans. When the job market is favorable we usually find fewer students going on to graduate school and more graduates still considering job offers. And, of course, when the job market is favorable we have fewer graduates with no offers or plans. When the job market is less than favorable we find an increased number applying for graduate school, a higher percentage with no offers or plans, and very few still considering job offers, since they are quick to accept a fair offer when it is made. As you can see from these numbers, 1979 presented a favorable job market to the graduates.

Figure 12 shows the statistics for aerospace graduates, with the number employed as of the date of graduation slightly lower, the number entering full-time graduate study slightly higher, and the

number of graduates with no offers or plans about 1 percent higher than the average. The statistics are slightly lower than for some other disciplines, but really not that far out of line.

Figure 13 shows the progress in salaries for engineers by degree level from 1963 to the present. As the graph indicates, engineers have made good progress. Figure 14 indicates that aerospace engineers have also made good progress salary wise. Figure 15 shows a comparison of the starting salaries paid to engineers in general and those paid to aerospace engineers. Although aerospace engineers were somewhat behind over the past decade, apparently they've now caught up with the average. I would now like to share with you some preliminary information that we have collected in our placement survey with respect to starting salaries for bachelors, masters, and Ph.D. engineering graduates in 1980. I should like to remind you that these are preliminary numbers and should not be considered official until our survey is published. As we all suspected, petroleum engineering graduates received the highest starting salaries of any engineering discipline at the bachelors level. At $1983 a month, their salary is higher than most starting salaries at the masters degree level. Aerospace graduates received starting salaries of $1655 at the bachelors level, which is somewhat below electrical and chemical, but higher than computer and civil. The average starting salary for all disciplines as reported in the Engineering Manpower Commission Placement Survey is $1720 a month. At the masters degree level, the average starting salary is $1898 a month. The average starting salary for aerospace engineers at the masters level is $1867 a month. At the doctoral level, the average starting salary for all engineering disciplines is $2313 a month. Aerospace engineers at the Ph.D. level receive starting salaries of $2235 a month.

Figure 16 shows engineering employment and unemployment in the United States. The Bureau of Labor Statistics estimates that we have about 1,400,000 engineers currently employed, with an unemployment rate of about 1.2 percent. It is estimated that aerospace engineers make up about 5 percent of the employed engineers.

I hope that this information will be of some value to you in your deliberations over the next several days. If you have any questions in the time remaining, I shall try to answer them. Thank you again for your kind attention.

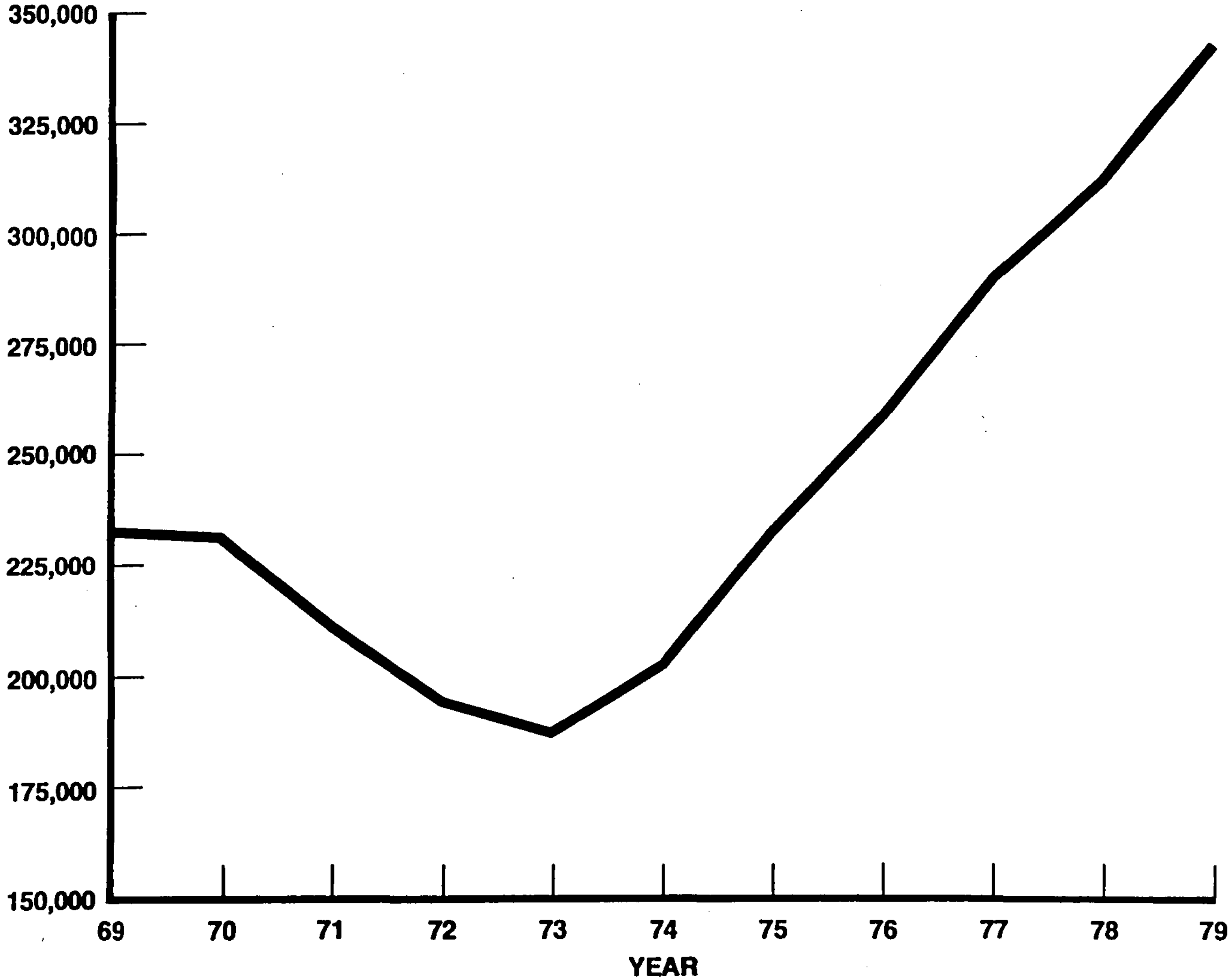

FIGURE 1 Total Undergraduate Engineering Enrollment

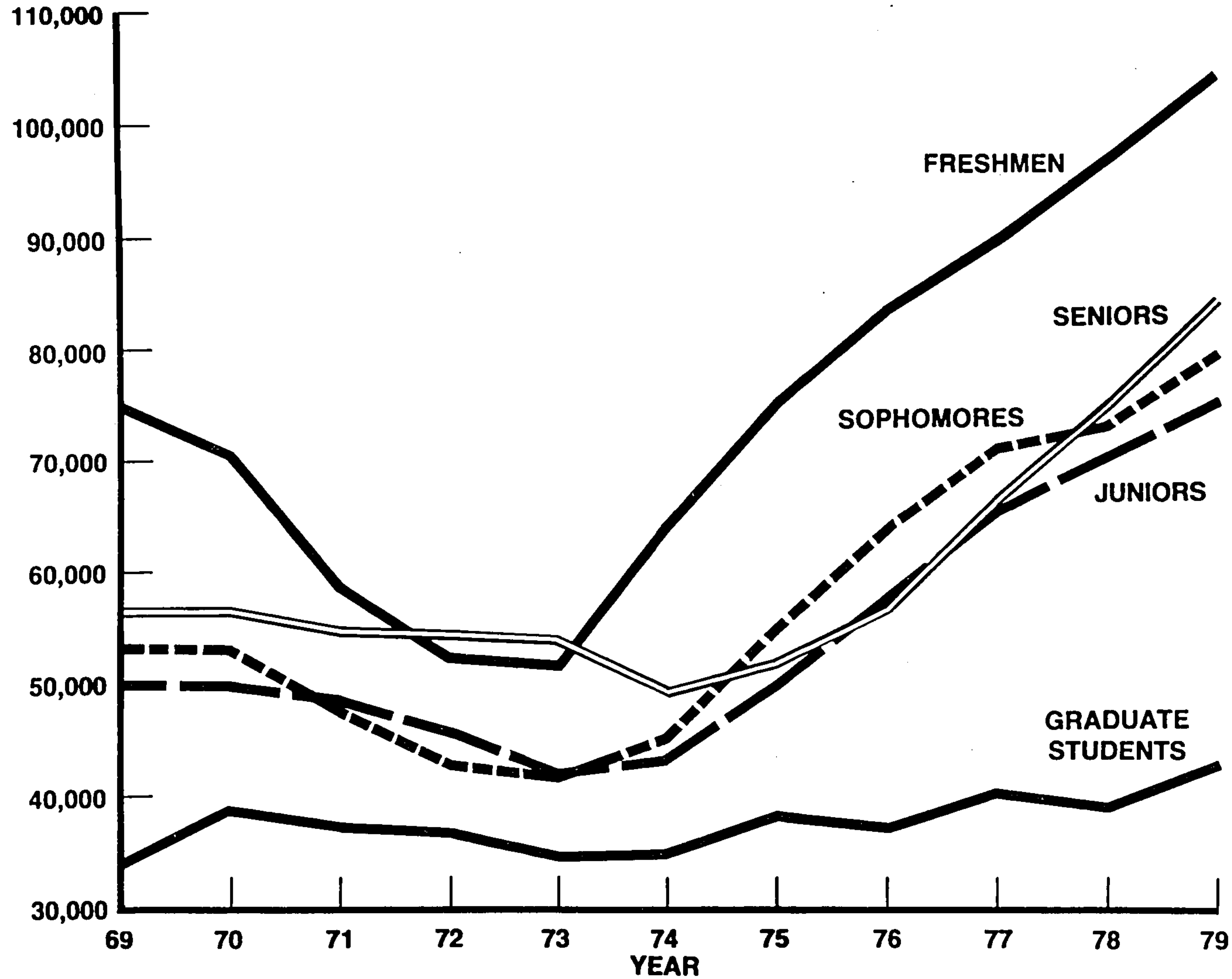

FIGURE 2 Engineering Enrollment

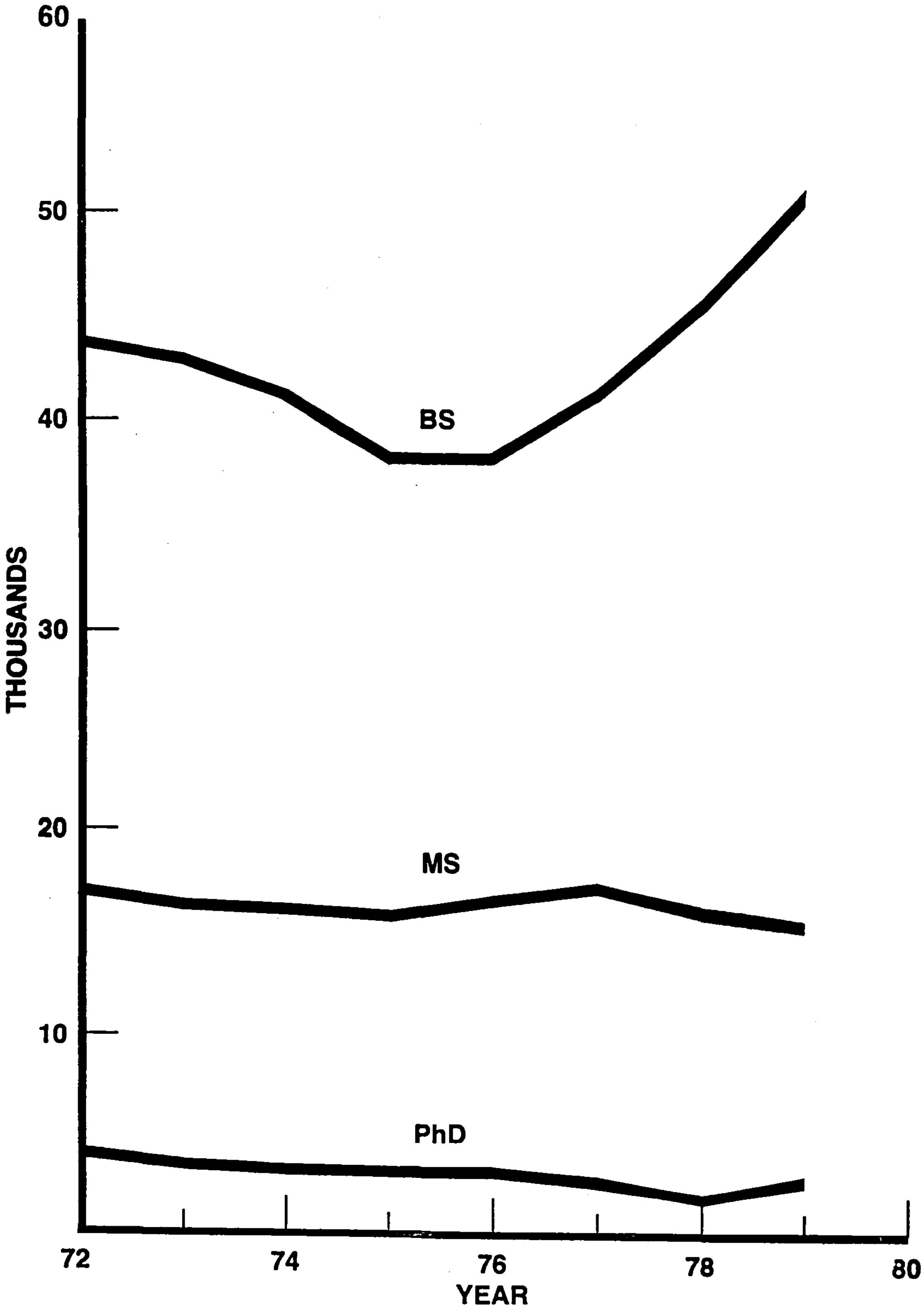

FIGURE 3 Engineering Degrees

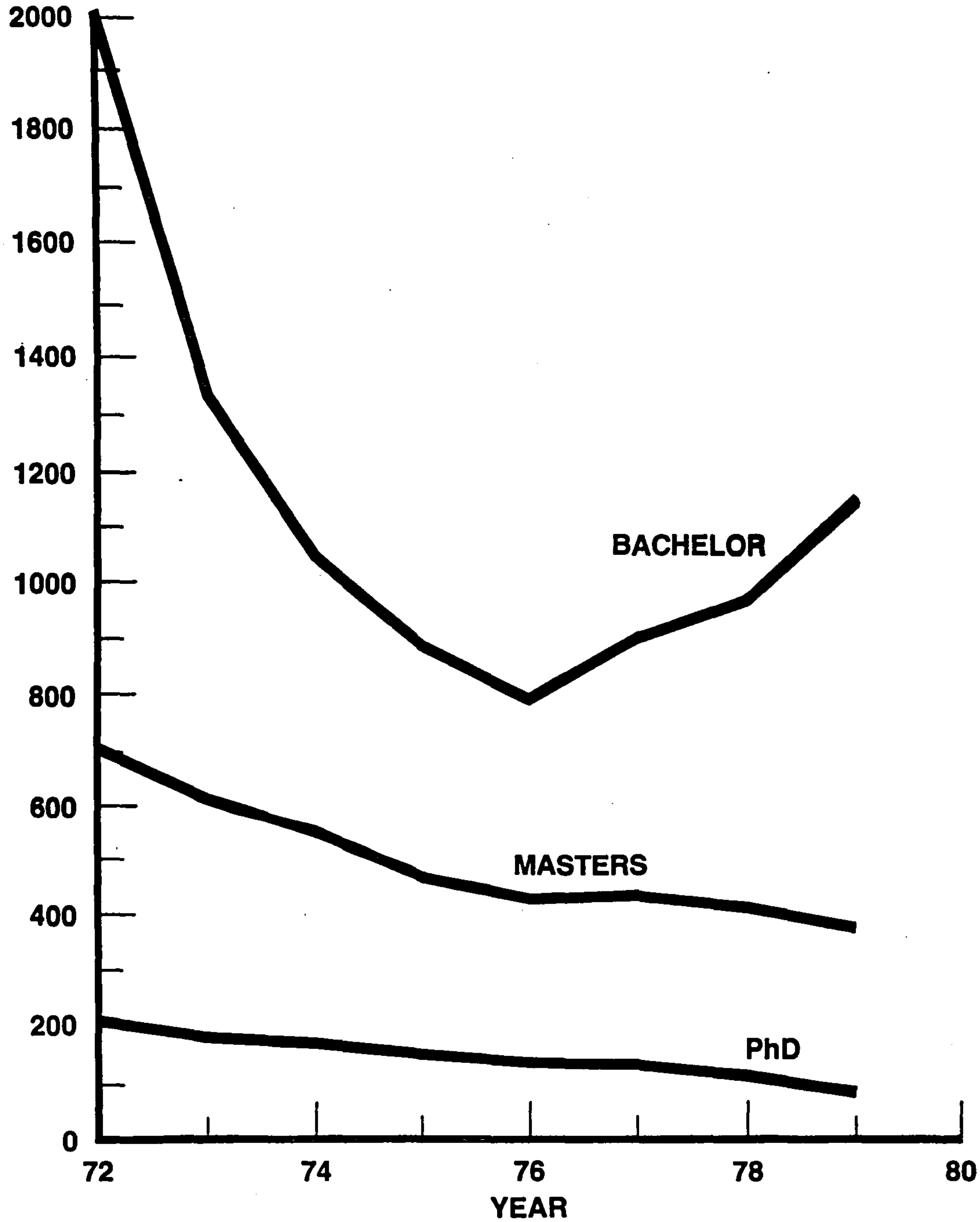

FIGURE 4 Aerospace Engineering Degrees

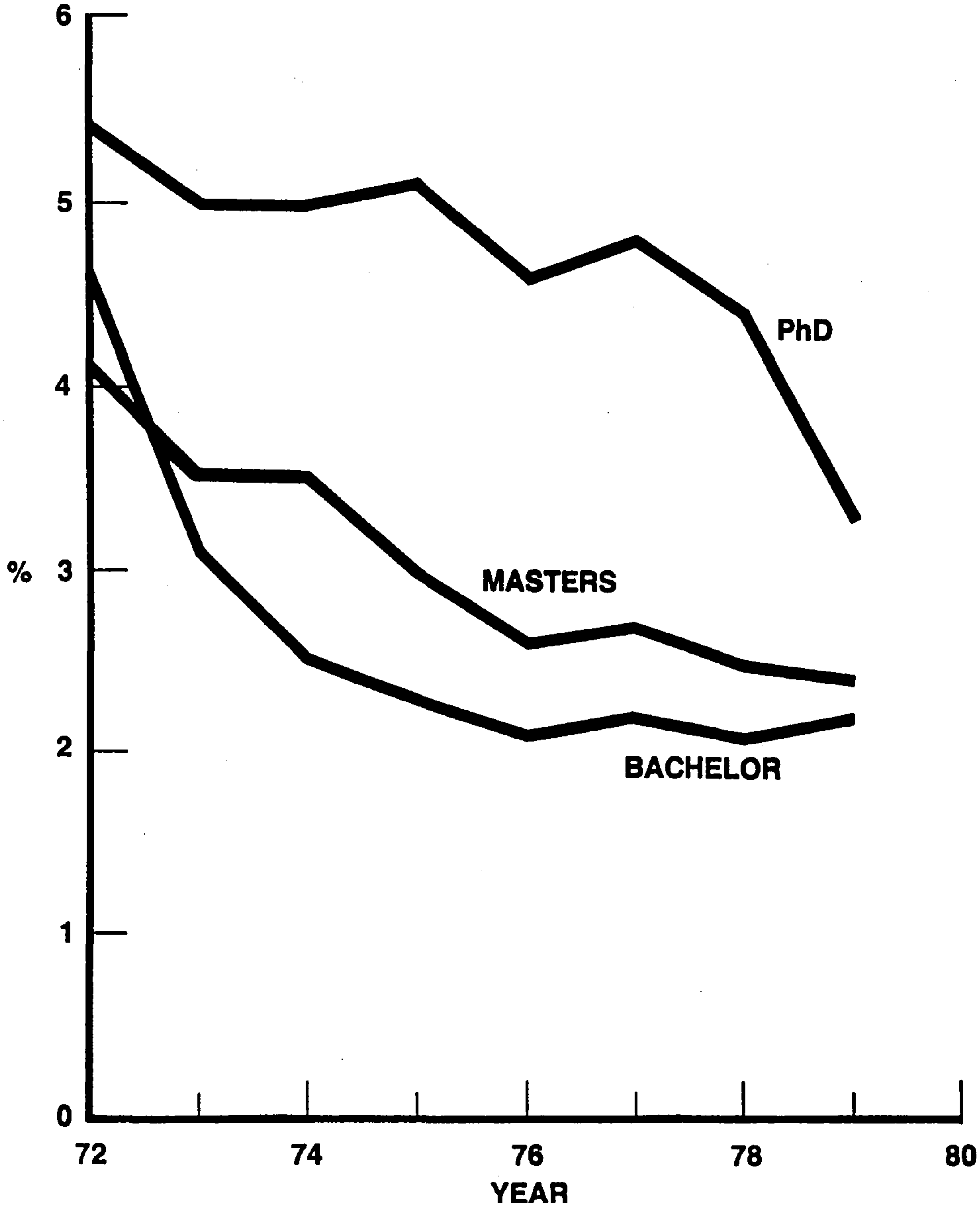

FIGURE 5 Aerospace Engineering Degrees as a Percent of Total Degrees Awarded

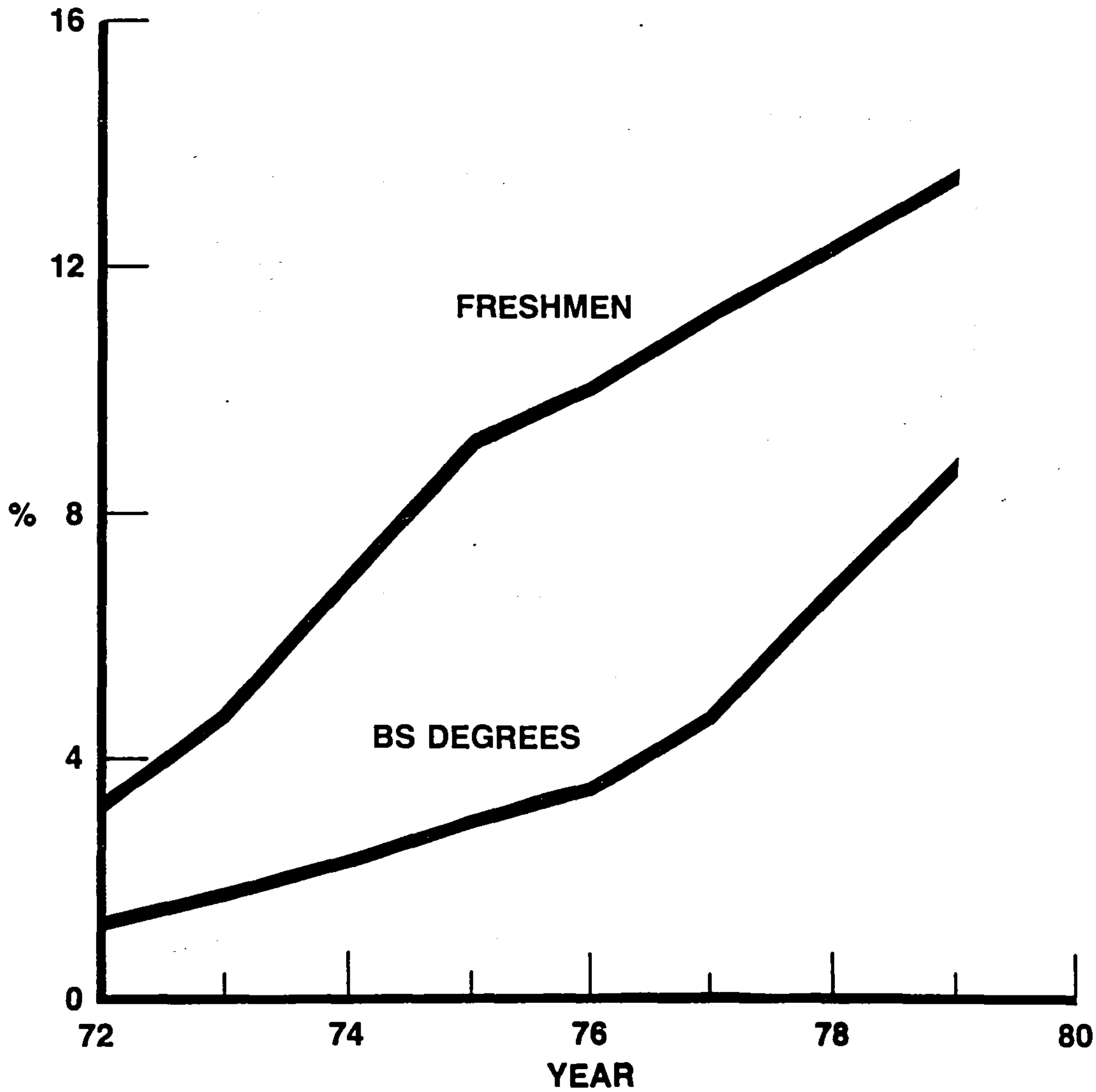

FIGURE 6 Participation of Women in Engineering

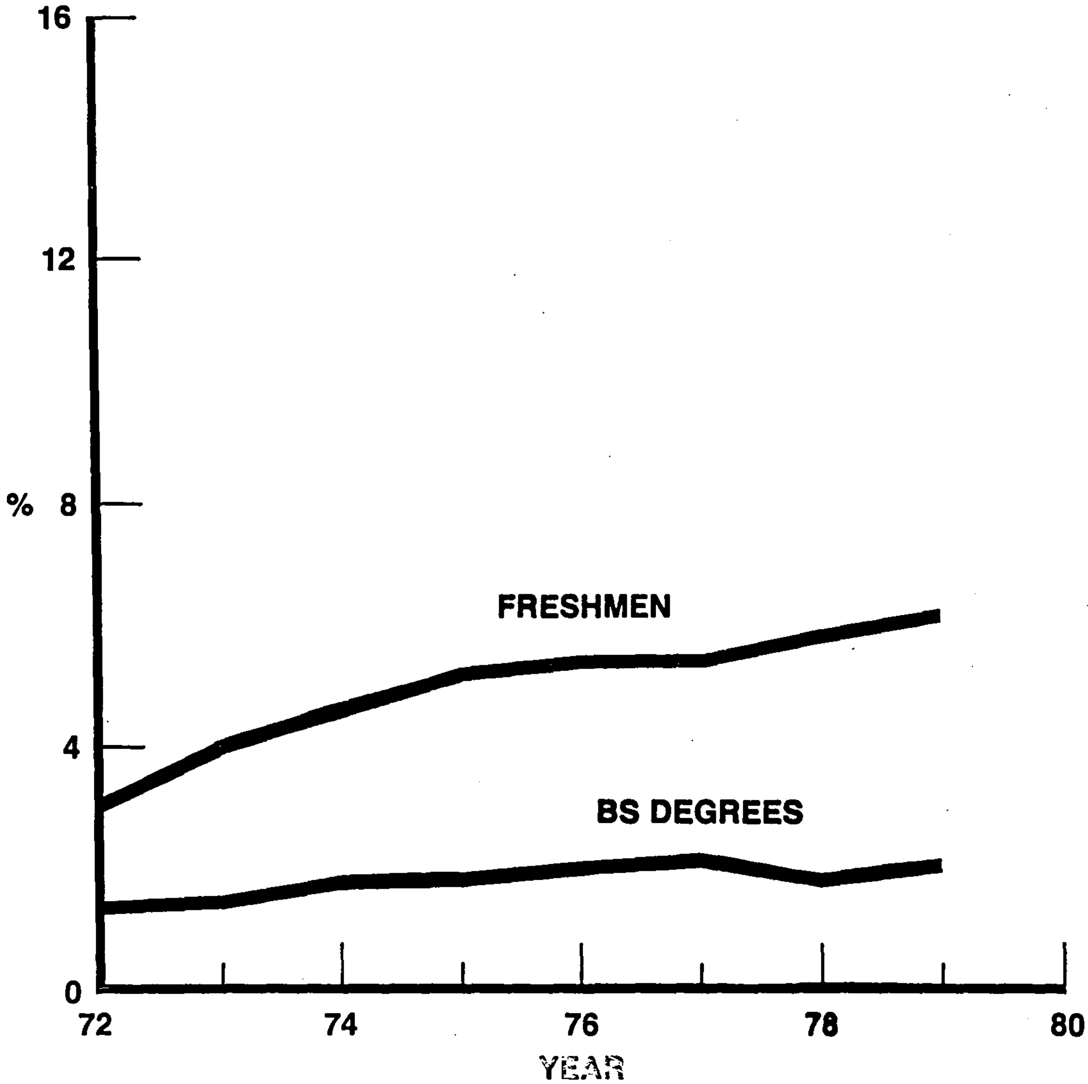

FIGURE 7 Participation of Blacks in Engineering

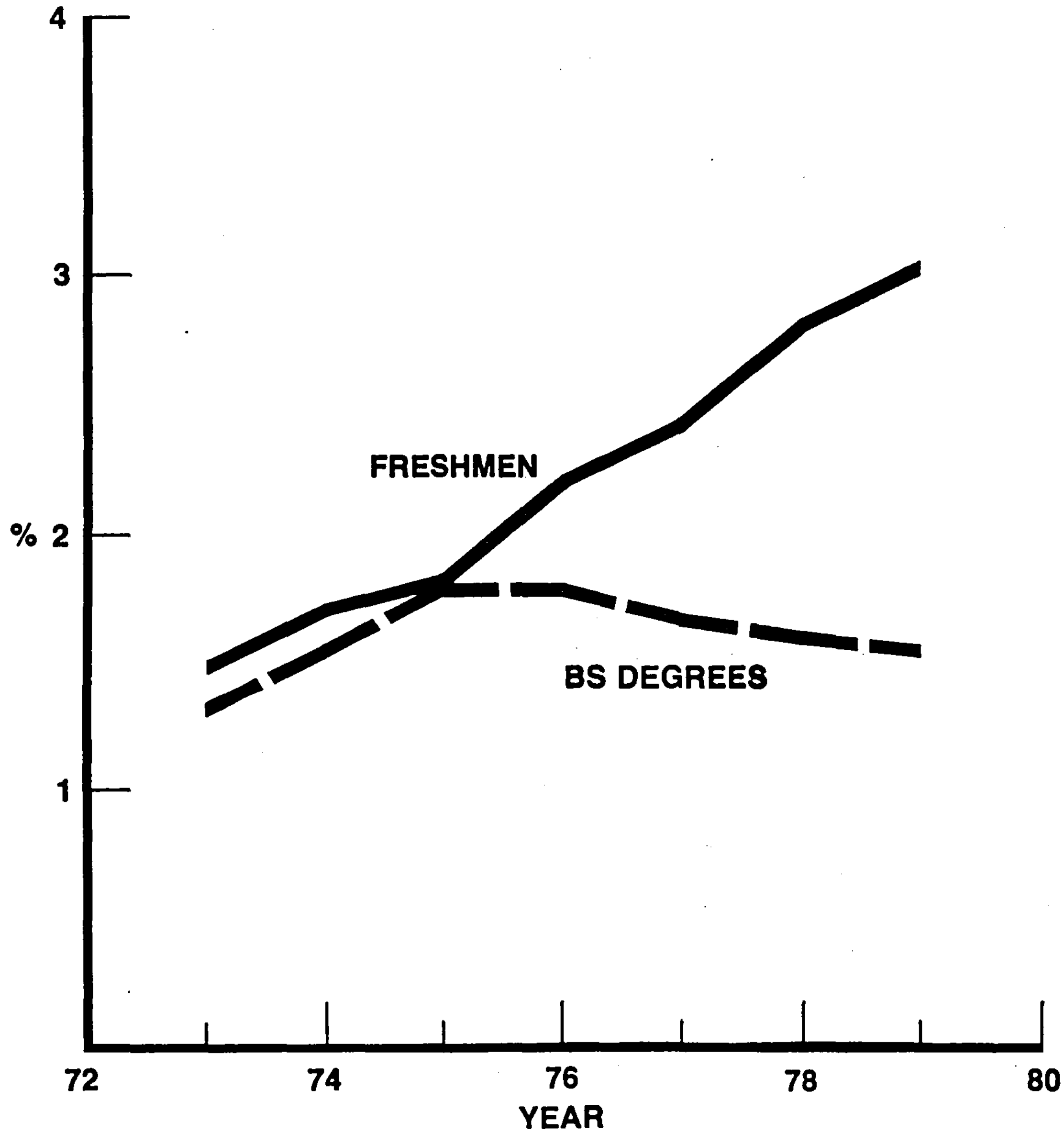

FIGURE 8 Participation of Hispanics in Engineering

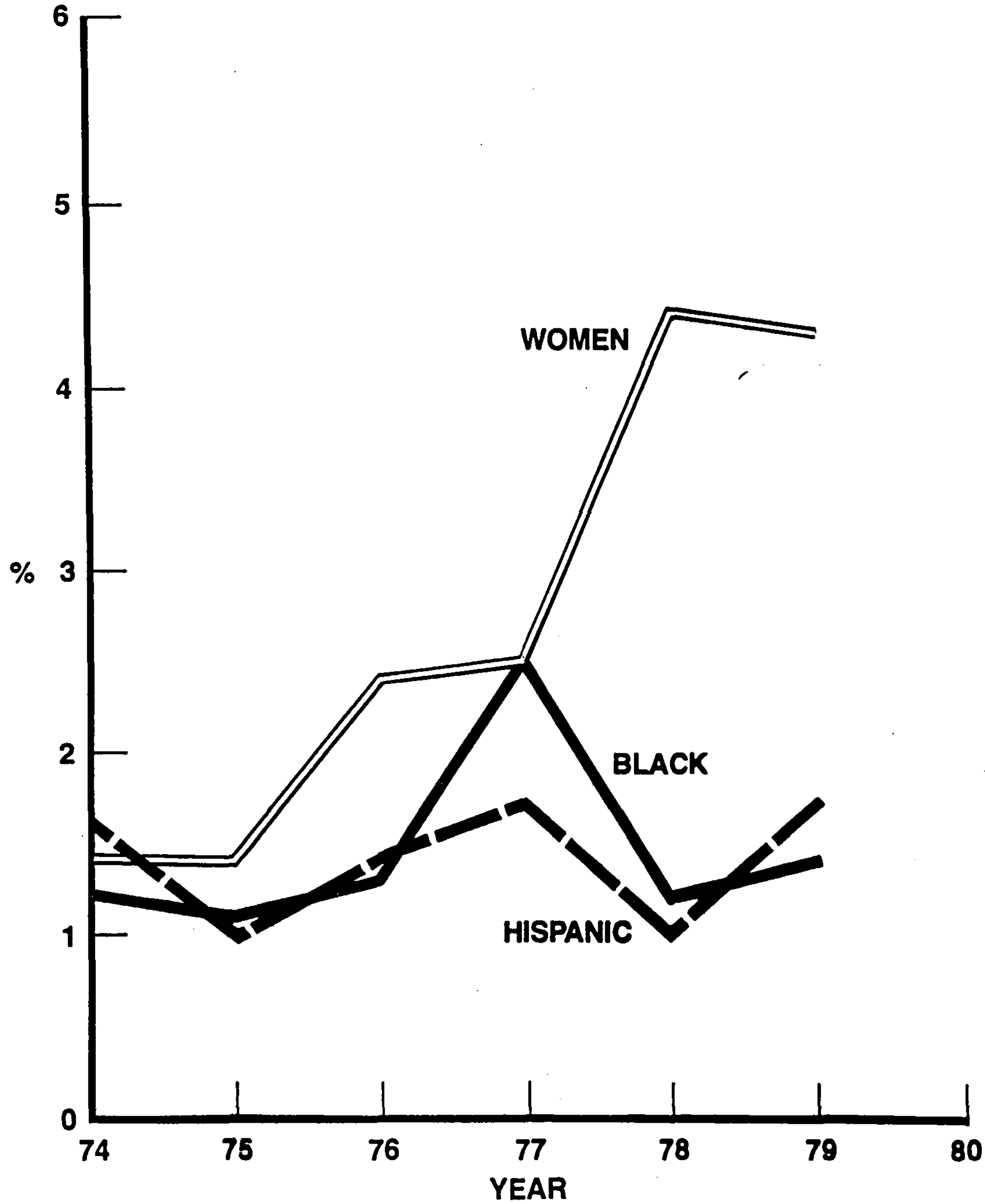

FIGURE 9 Aerospace Engineering--Participation of Women and Minorities by Percent of B.S. Degrees Awarded

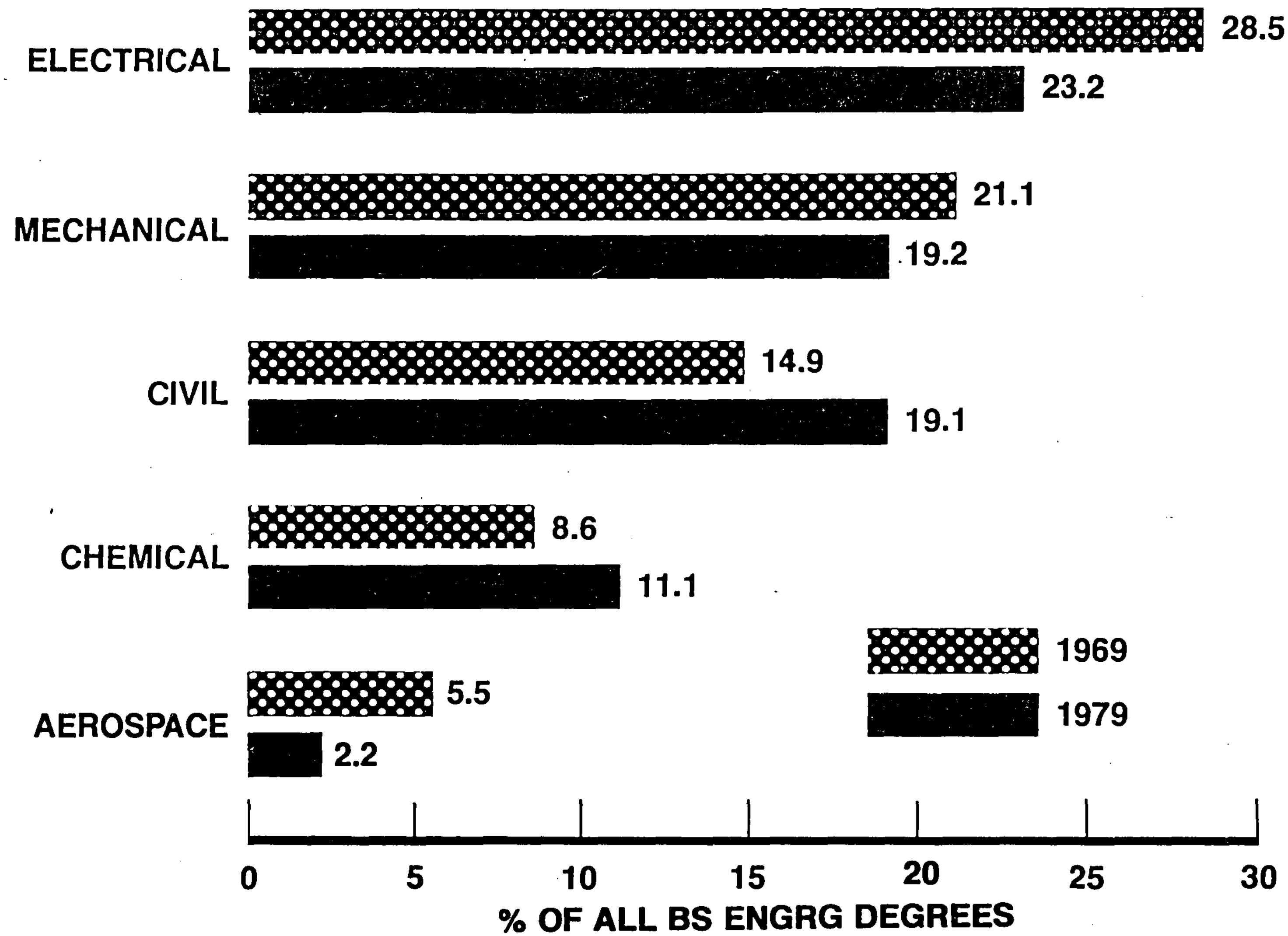

FIGURE 10 Engineering Curricula: 1969 vs. 1979

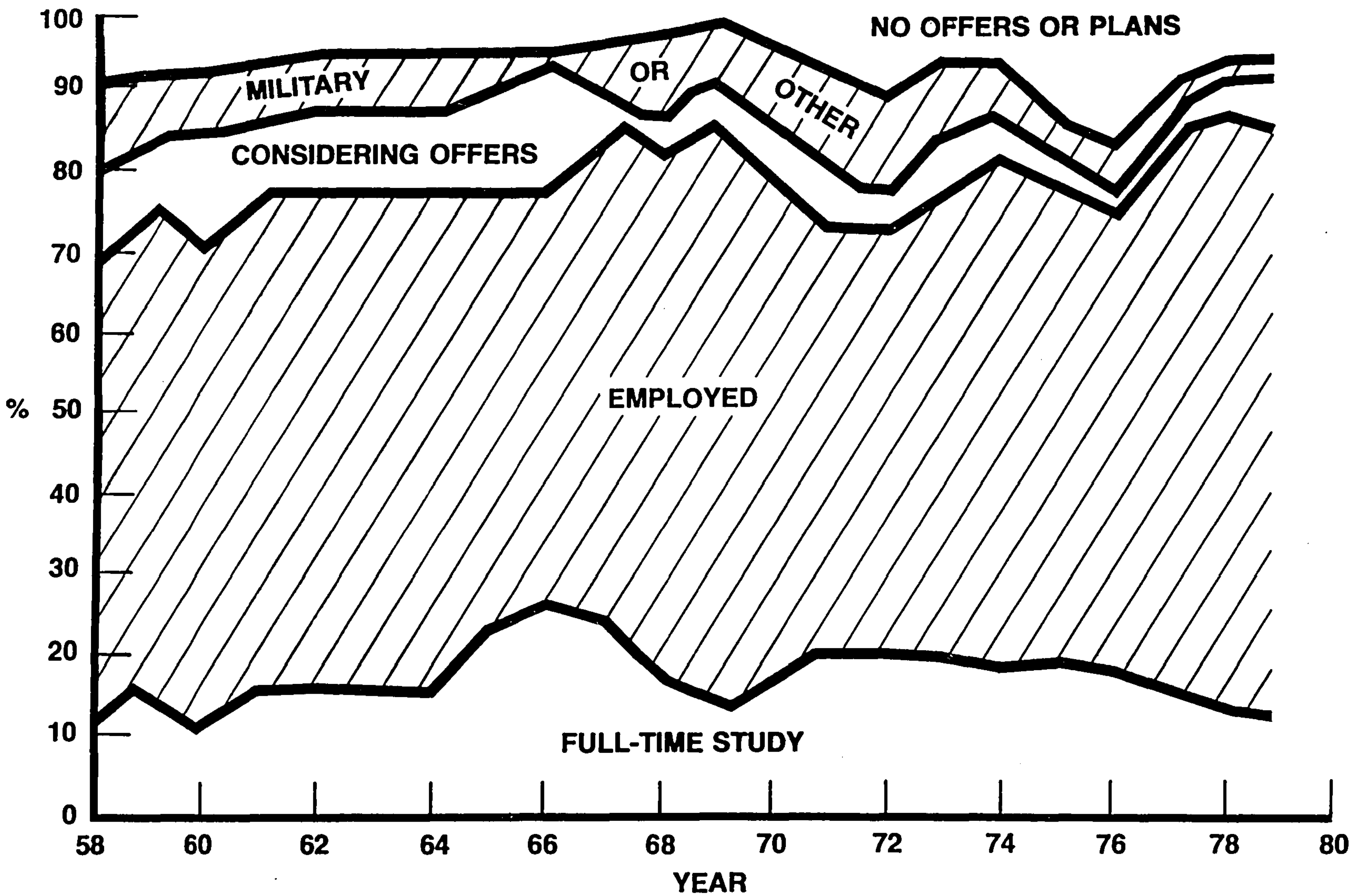

FIGURE 11 Placement Status--B.S.

PERCENT

	70	71	72	73	74	75	76	77	78	79
EMPLOYED	52	38	44	51	51	48	41	62	63	70
FULL TIME STUDY	17	26	20	16	20	21	22	17	14	14
OTHER PLANS	20	26	22	18	17	17	23	12	16	6
CONSIDERING JOB OFFERS	3	2	4	11	5	2	3	3	5	6
NO OFFERS OR PLANS	8	8	10	4	7	12	11	6	2	4

YEAR

FIGURE 12 Placement Status of Aerospace Engineering Graduates With B.S. Degrees

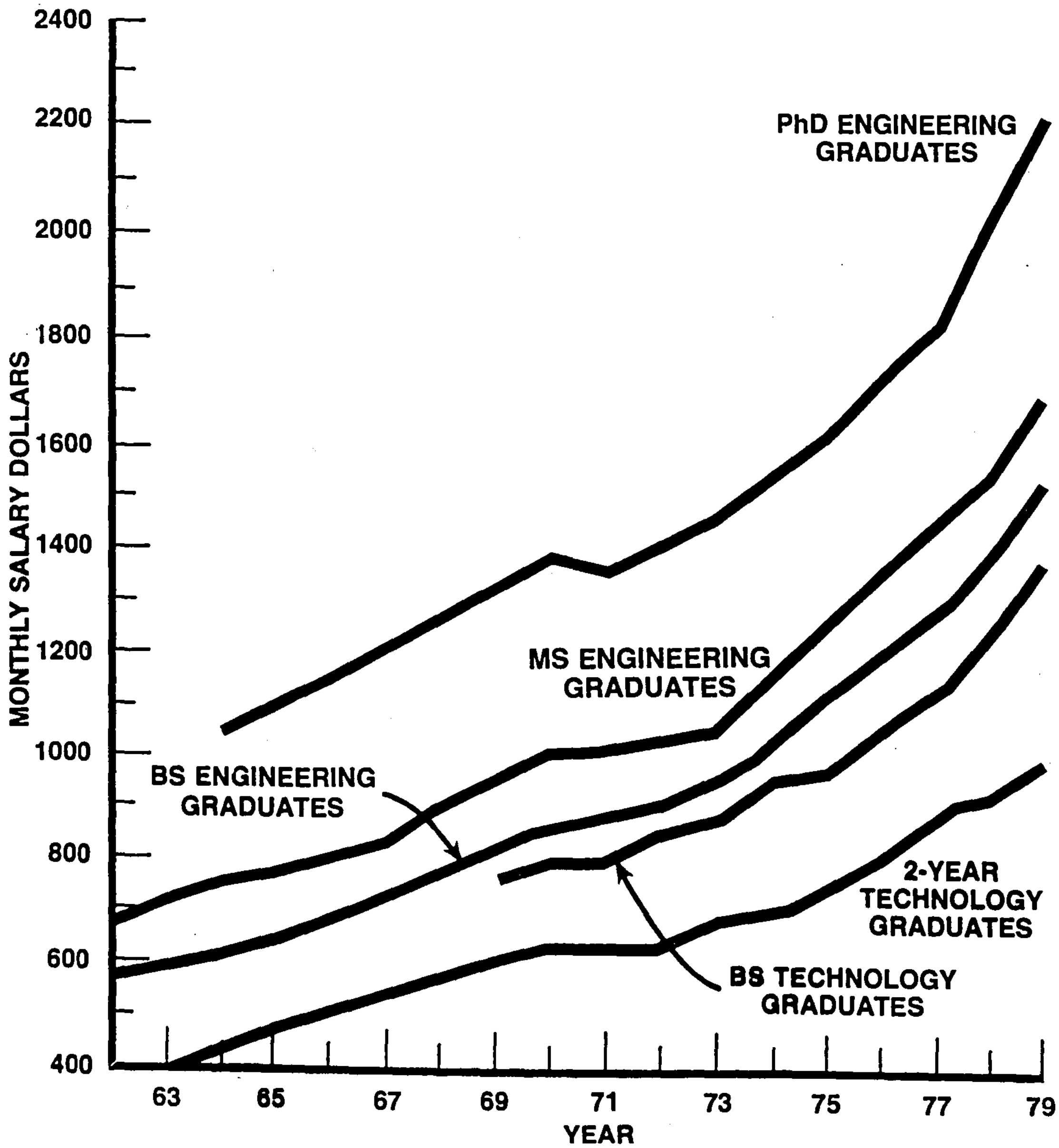

FIGURE 13 Average Monthly Starting Salaries

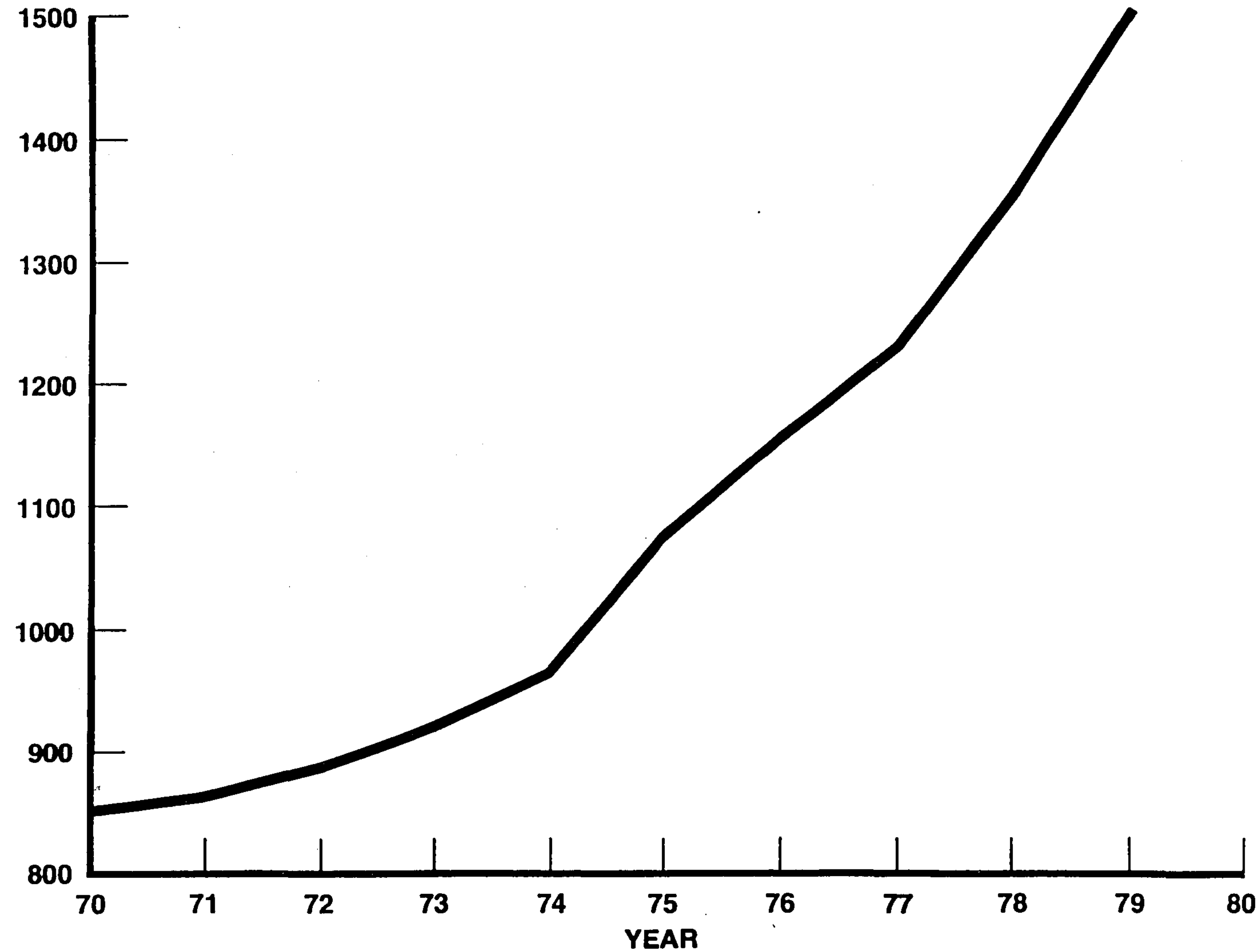

FIGURE 14 Starting Salaries of Bachelor-Level Aerospace Engineering Graduates

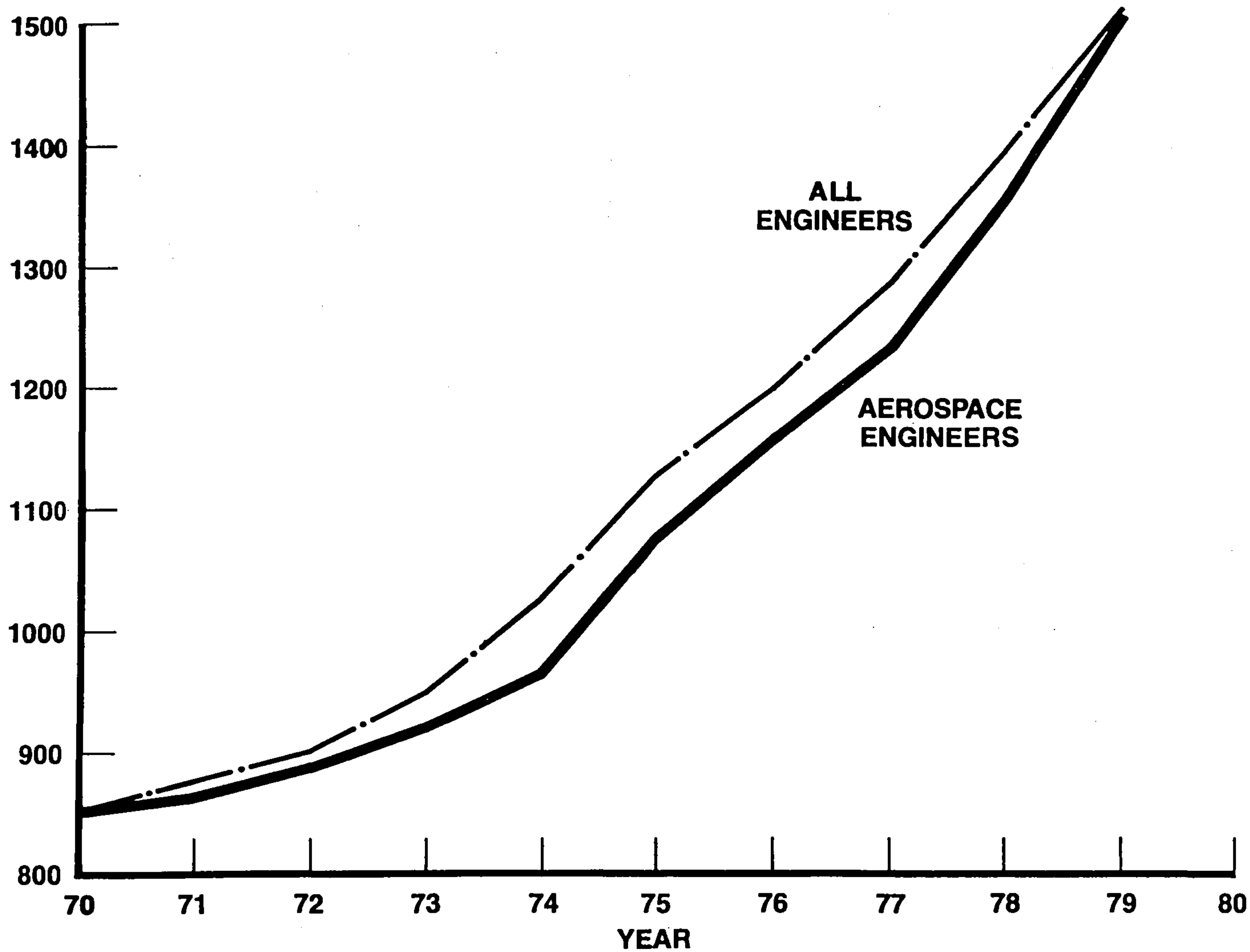

FIGURE 15 Starting Salaries of Bachelor-Level
Engineering Graduates

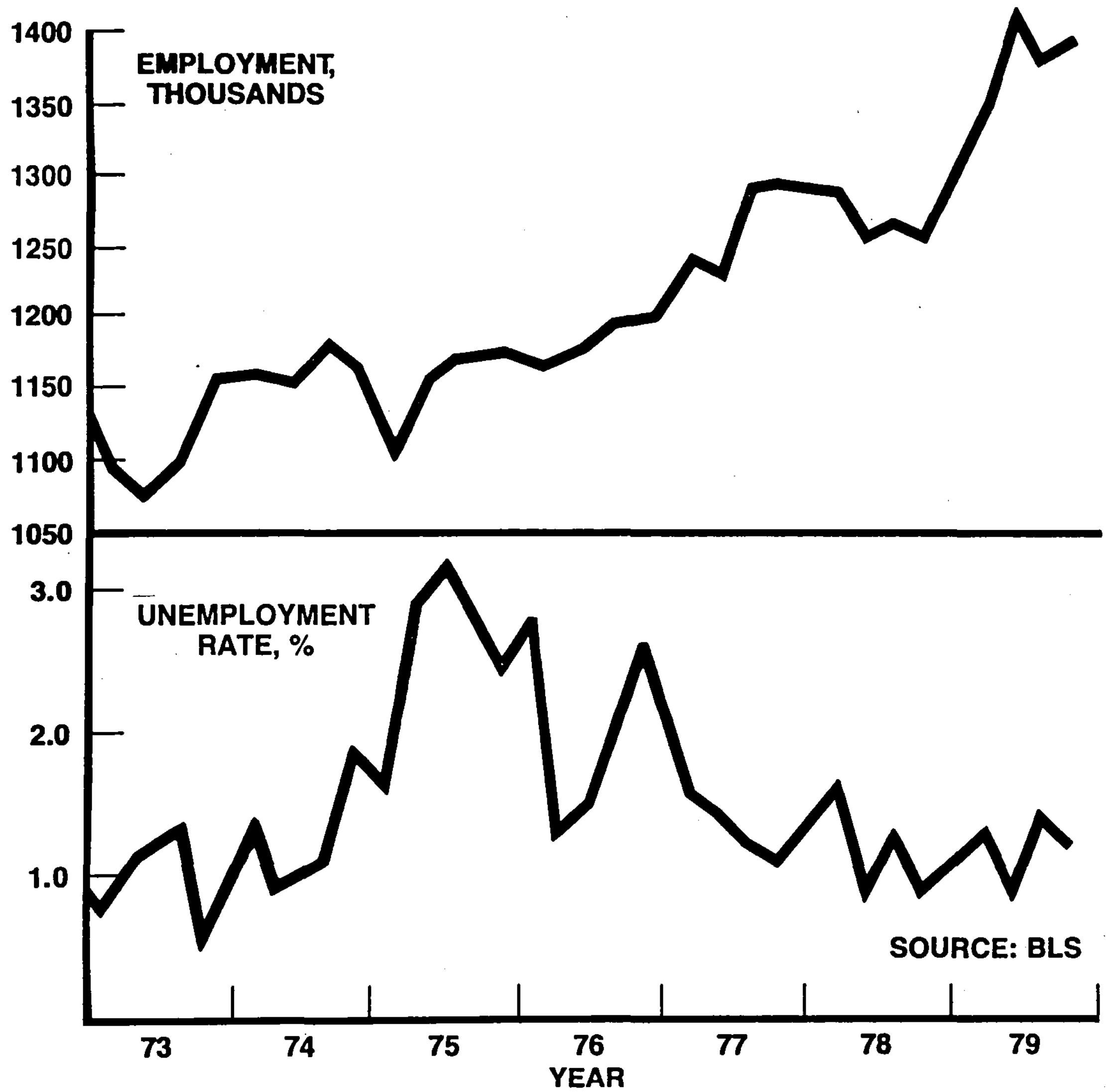

FIGURE 16 Engineering Employment and Unemployment

THE OUTLOOK FOR METALLIC MATERIALS

Charles Law McCabe
Vice President and General Manager
High Technology Materials Division
Cabot Corporation

Perhaps I should retitle this talk "What Should We Do About Metallic Materials," rather than merely consider their outlook. That's because what we in the U.S. decide to do today and tomorrow will so profoundly affect that outlook. Essentially, then, my remarks will deal with what I think we should do to brighten the outlook for specialty metals, which are the ones I know the most about and the primary ones at issue.

Coming from a private sector organization that has a long history in developing specialty metals, I might be expected to sketch either a flattering portrait of our industry's future or a dismal one--depending on the point I might wish to make. But it is because I am a part of an industry whose future depends on the eventual outcome of the issues we're discussing here that I conclude that the outlook for metallic materials depends, to a large extent, on industry and government working together. And as a former college professor, I'll add the academic community to that.

To pick up the "outlook" thread, I'll divide it into three parts:

--Today, it's not all that bad.
--Tomorrow, it's dubious.
--The day after, it could be disastrous; or, on the other hand, under control--which it will be is up to us.

The current boom in the aerospace industry has seen a period of metallic raw materials allocations and for wrought alloy producers lead times measured in months, even years (rather than weeks). In addition, it has been a period of rapid price increases all the way around.

Although the acute shortage phase is over, we are still left with

some metallic raw material prices that are artificially high and cannot be sustained over time.

I refer particularly to cobalt, which shot up in price during 1978 and 1979, from $6 to $25 a pound. Unfortunately, most of the free world's cobalt comes from Zaire and Zambia, countries that are desperately in need of cash. Political considerations, rather than marketplace pressures, therefore, dictate selling price.

In time, the cobalt price will come down. Generally, though, we shouldn't expect metallic raw materials prices, which have escalated far faster than inflation, to come down. Therefore, pressures that have always existed to find ways of reducing materials costs will be intensified, and good ideas will readily be funded.

As for tomorrow, shortages such as we have experienced can be expected to occur again, given the fluctuations in demand by the aerospace industry coupled with a general increase in demand by other markets. The private sector has responded to this situation. Both primary metallic raw materials producers and wrought alloy producers have announced expansion plans.

In my own division, our production today in pounds is twice the rate we enjoyed during the peak of the 1974 boom period. And just last week we signed a contract that, in 1982, will more than double our capacity, as well as improve raw material utilization by increasing yields.

With this expansion, we hope that we'll be able to keep our delivery times down in the next boom period so that our customers won't have to order material so far in advance and wait so long for delivery.

In most cases, the profit-making system will work in time to provide the necessary productive capacity. But this isn't the whole story and it certainly isn't for the day after tomorrow because there must be an adequate supply of minerals or metallic raw materials to feed the productive capacity and that supply is limited for some important metals.

We in the U.S. are particularly vulnerable because 18 of the minerals considered essential to our economy and security are imported at levels of 50 percent or more. Close to 100 percent of two of the most strategic metals for the aerospace industry--cobalt and chromium--are imported.

Given that the demand for metallic materials fluctuates and that we import so many of the vital allowing elements, some way of bringing supply and demand into synchronization without worrying about possible cutoffs of foreign sources seems to be the way to go.

How best to approach this admittedly idealized situation is the main point I wish to leave with you. Permit me to arrive at this point by summarizing the existing and near-term supply and demand situation and then identifying some basic ideas concerning alternatives to our dependence on foreign existing supplies.

The alternatives, each of which I will address, are as follows:

--Substitution of those metals whose supplies are most vulnerable to political and other upheavals around the world.

--Designing around--that is, eliminating or reducing--the amounts of those metals now being used.
--Recycling, or salvaging, those metals during production of components and their eventual disposal.

First, I will discuss the outlook for supply and demand over the next five years, focusing on some of our vital and vulnerable strategic metals.

Chromium By any criterion, chromium is at the top of the list as a source of concern to anyone who supplies high-temperature alloys to the aerospace industry. The reasons, of course, are that virtually all our chromium is imported and all high-temperature alloys contain about 20 percent chromium for oxidation resistance. The predominant world reserves are in the Union of South Africa and in what was Rhodesia, a region in which there is a great deal of political unrest. Because of its importance and because we don't know what else to do, my company is stockpiling chromium, just in case.

Cobalt The high price of cobalt and the experiences of the recent cobalt shortage have spurred mining and extractive metallurgy programs in North America to lessen our dependence on southern Africa.

Tantalum The demand for highly efficient, yet miniaturized, circuitry for electronic control devices in applications ranging from defense and automobiles to household smoke detectors and electronic games has placed unprecedented demand on the limited availability of tantalum. Tantalum powder prices have escalated by a factor of five. The best hope now is the discovery of new mineral deposits.

Tungsten This is one of the metals that the U.S. possesses and can accommodate about 40 percent of its own demand. Demand is about 20 million pounds, with 10 million pounds being imported (mainly from Canada and Bolivia). During this past boom, tungsten behaved itself--largely because it was avoided in earlier R&D programs because of price and supply, because new productive capacity was installed in response to past shortages, and because the tungsten carbide industry learned to recycle using physical processes that are cheap and quick.

Nickel Free world use of nickel is about 1.2 billion pounds a year. Most of the 400 million pounds of nickel used in the U.S. is of Canadian origin. Many new mines have been developed in recent years, and currently there is more potential capacity than demand. However, the cost of bringing on new mines has escalated so much that real prices will have to rise for them to be economical.

Molybdenum The cost of molybdenum has risen 77 percent (from $9.10 to $16.20 a pound) since January 1, 1979. The U.S. is self-sufficient in this critical metallic element. Considerable new production is planned through 1987, which should support the forecasted growth rate. Beyond then, new sources will need to be developed, at significant cost, which could very well exceed the capability of any single corporation.

Columbium Large columbium reserves have been identified in Brazil, and production will be expanded to produce about 55 million pounds a year of this metal.

So much for the current situation--now, there are many ways to increase metals supplies: keep world reserves of strategic minerals in friendly hands, increase prices to spur exploration for new sources and exploitation of leaner ore bodies, and do more R&D on extracting metals from lean ore bodies.

The big payoff in supply over the long term, however, will be found in other ways. One of these is materials substitution.

Substitution in metals can take three avenues: use of other metals or alloys, use of metallic or nonmetallic coatings, and substituting nonmetals for metals. Obviously, substitution is not new, and all these avenues have paid handsome dividends in the past.

In the past we have most often substituted to obtain better performance. Now, faced with uncertain mineral supplies, we are looking to substitution to help alleviate the situation or, as we hope, solve the problem.

My division has had some recent R&D experiences in substituting nickel for cobalt--experiences that I would like to share with you.

Our R&D program to develop a no-cobalt wrought alloy for the combustor can in gas turbines arose because of the $6 to $25 a pound increase for cobalt I mentioned at the start. Even at that price, we were on allocation and facing the sobering alternative of paying $40 a pound on the merchant market. The need for a nickel-base alloy with properties as good as the cobalt alloy was, thus, obvious and highly desirable, so we set to work right away.

During the past year and a half we have made remarkable progress in this R&D program because of the large volume of scientific information already in the literature on phase diagrams, metal carbide compositions and morphology, diffusion coefficients of metals in alloys, and the elements of strengthening mechanisms. Without these data, we would not have been able to make nearly as intelligent guesses as to what systems were most promising and we would have been forced to do a great deal of Edisonian-type research.

The basic lesson to be learned from this experience is that, in substituting metallic systems in aerospace applications, where the combination of properties required is very specific and very demanding, it is not practical to amass a storehouse of knowledge to deal with every substitution possibility that might be needed.

What is needed is more basic scientific data that can be used by researchers to speed up the process of alloy development. Then, as the need arises for a substitute alloy or for a new alloy, it can be developed in a timely fashion.

I am not advocating that we, as a nation, do less scientific investigation of the mechanisms of time-dependent processes, such as oxidation, creep, or low-cycle fatigue. Rather, I am saying that we in the U.S. should support more research work aimed at broadly gathering data on systems of potential interest for alloy substitution.

This is one of the areas that NASA can boost markedly, chiefly via increased support of research directed toward such data gathering--in universities, government laboratories, and private industry. Certainly, this is an area for cost shaving and one for cooperative R&D programs.

We now come to design.

History tells us that in the aerospace field the outlook for materials at any given time is intimately tied up with future design. In turn, future design often depends on developments in materials. Today, the need for reduced fuel consumption, reduced weight, increased reliability, and decreased manufacturing costs clearly calls for continued close cooperation between the design and the materials communities.

My own experience convinces me that there is room for improvement. I know that in our own allocation of resources to various R&D areas we spend very little of our own funds or time on meeting future needs of design engineers because many of the uncertainties involved. We just do not, in the normal course of business, meet with the key design engineers in industry or government.

We would be pleased to spend more of our R&D effort in this area if mechanisms were set up to better define what needs to be done and if the tasks to accomplish this were split up according to the special expertise of the cooperative private or government organizations. I am sure that other metallic materials producers would be receptive to such a program.

Conventional high-temperature metallic materials for gas turbine use have been approaching the limit of development for some time--except now it appears that dispersion-strengthened alloys have a great deal of promise. It is for this reason that there has been increasing emphasis on design to attain the objectives mentioned above. What can materials suppliers do to help?

First, materials suppliers can provide product forms and physical characteristics that would be amenable to the new designs and, in some cases, to new manufacturing practices to make the newly designed components. Indeed, we as suppliers of high-performance alloy sheet, bar, plate, wire, and tubing can envision that we could add to that list certain fabricated forms that lend themselves to production in large-scale equipment that we would add to our conventional wrought alloy mill equipment.

If required, we can respond to the need for wrought alloys with better welding and fabrication capabilities. As materials are used more efficiently (that is, thinner and in more complex parts), oxidation resistance may become a difficult problem to resolve, requiring responses from different segments of the materials community.

Let us now discuss some other avenues we can take to help us adjust to the materials problem.

First, alloy design. In designing alloys, the following should be considered (in addition to meeting design targets):

--Future availability and cost of raw materials.

--Avoiding the loss of strategic elements in melting returned scrap.

--Ability to process in existing large-scale equipment.

Second, techniques that allow better utilization--specifically, shaping instead of removing metal--are among the most rewarding actions that can be taken to make the best use of critical materials. Much already has been accomplished in this area, such as producing parts to near net shape using P/M techniques, but a great deal more needs to be done. Still, far too many cutting chips and too much grinding swarf are generated. The pity is that many of the alloys in them are not returned to their optimal economic use because they are irretrievably mixed with less expensive alloys.

Finally, the above leads to a subject that is of fundamental importance to both the short- and long-term solutions to materials shortages and high costs.

It is clear, I'm sure, that the best way to conserve materials is to reuse them. For this to happen, complete cooperation of three groups is mandatory:

--First, the alloy producer. He must segregate his internally generated scrap and develop techniques and procedures for melting purchased scrap in grade and encourage his customer to return scrap in grade by paying good prices for segregated scrap.

--Second, the fabricator of high alloy parts. He should keep grindings and metal chips from diluting a grade, or at least keep cobalt-, nickel-, and iron-base alloys separate. He must also return these high-grade materials to the original producer, thus preventing them from finding their way into products where some of the strategic elements are not needed to meet specs.

--Third, the engine designer. Where possible, assembly should be designed so that different alloys (or families of alloys) can be easily separated when the assembly is finally scrapped, so that the alloys can be sent back to the alloy producer for melting-in grade.

The materials outlook for the 1980s is such that we simply cannot relax. We have a great many options open to us for short-term solutions to materials availability: we can explore for new deposits, develop known deposits, stockpile in times of recession, and keep the Soviets away from our sources of supply.

For a long-term solution to our materials availability problem, however, we must look to substitution, design, and a tight scrap return cycle. These solutions are not new; they have a long and honorable history. But it is not too soon for us to accelerate developments in these areas.

THE 1980S:
A DECADE OF REVITALIZATON FOR AVIATION

Dr. Bill Wilkins
Associate Administrator for Policy and
International Affairs
Federal Aviation Administration

Thank you for the opportunity to speak at this meeting. I bring you greetings from Administrator Langhorne Bond and his wishes that you have a productive session. Today I want to share with you some views about the future of air transportation from the viewpoint of the FAA's Policy and International Aviation Affairs organization, which I head.

API, as it is called in the agency, has among its functions policy analysis, planning, and international aviation affairs. As such, we may have many of the economists and systems planners of the agency within our organization. There are relatively fewer engineers among us than you would find elsewhere in the FAA. The engineering and regulatory parts of the agency are well represented by other people on your program who will be here all week. I bring to you today the perceptions of an economist regarding the future of aviation.

Over the last several decades aviation has grown to maturity. Air travel, whether in a large jet transport or small private plane, is no longer the novelty or adventure that it once was. Aviation--and the opportunity it offers for safe, high-speed, long-distance travel--is a part of everyday life. The safety, comfort, and convenience it provides are taken for granted by most of the population. The air transportation industry has evolved to the point where it serves many markets encompassing a broad cross section of society.

Along with this growth to maturity has come the establishment of a large infrastructure that we refer to as the National Aviation System. A network of airports, navigation systems, and air traffic control facilities have been built to serve the hundreds of thousands of aircraft that now operate in the United States. Aircraft technology has advanced to levels of sophistication that few even dreamed of not so many years ago. What has evolved is a complex,

interrelated system of people, procedures, and capital plant that demands a careful balance of a multitude of variables and, I believe, cooperation among all system elements i.e., government, industry, and users.

Let me reinforce a point that was partially addressed earlier today--which is one of the advantages or disadvantages of speaking later in the program. As aviation has grown to maturity in the United States it has also advanced substantially in the other industrialized nations of the world. Since at least the mid-1940s, the United States, has held a dominant, if not unassailable, position in the international aviation community. Although the United States clearly remains the leader in aviation, the era of our overwhelming dominance in the world marketplace and international forums is disappearing. We must now negotiate and compromise to a degree unknown for generations.

This has been much on our minds because the 23rd Assembly of the International Civil Aviation Organization will be held in September and October. Looking around this room I would guess that most of us grew up and did some of our most productive work during the time period that started as the great depression turned into World War II and ended with the close of the 1960s. That was a period of time when the leadership role of the United States was so clear it became easy to believe this was normal. Instead of being normal, it was, perhaps, a historical accident born of the prostration of our allies and former foes as well as our own strength. It was a dominance that we would not reasonably expect to happen in other times and other places.

Much has changed since that era--and not just in aviation. For example, the international monetary system created at Bretton Woods at the end of World War II has been substantially changed in the last few years. The United States dollar no longer serves as the world's only reserve and trading currency. The military hegemony of the United States has been challenged in many parts of the globe. Similiar industrial examples could be drawn, many of them automobiles, steel, electronics, and oil. The U.S.-based system of pricing world oil, which worked for a generation, has changed dramatically with the emergence of OPEC. We could draw on many examples, not just in the field of aviation, that illustrate challenges of the leadership role of the United States.

As a mature industry, aviation is now in much the same position as the other modes of transportation. In the federal government, as in the private markets, aviation must compete for a share of the limited resources available to the transportation sector. This becomes more important when viewed from the perspective of the substantial capital investments needed in the near future for replacement of ground equipment in the federal portion of the National Aviation System. In the early development of the aviation system, most of our capital investment was focused upon addition of new equipment to the inventory. Now, however, we are entering a phase that will require large capital investments in replacement equipment--leading to either less net expansion of the system or substantially increased funding levels.

In these times of increasing scrutiny and fiscal conservatism it will, indeed, be a difficult task to obtain substantial funding increases from general tax revenues. Even the often heralded trust fund "surplus" will cover only a fraction of the expected needs. We must find less costly, more efficient ways of doing things. We must do more by developing the technologies that help our people work more productively.

Cost and resource problems are becoming increasingly critical throughout the aviation community. Much of the capital plant of the airlines has reached the point where it will require replacement. Several years ago the capital needs of major airlines for the decade from 1976 to 1985 were estimated at $20 to $30 billion. Furthermore, it was estimated that they could more than double that amount for the period from 1976 through 1990. These estimates recognized that, in the mid-1980s, the airline industry would be entering its first major equipment replacement cycle since jet transports replaced piston engine aircraft. Although this was recognized as a major challenge, until recently most industry analysts believed that the airlines could "work out" any cash flow and balance sheet problems to provide the needed captial.

The last few years have added new dimensions to the problem. Inflation has reached higher-than-expected levels. Fuel costs have soared. Competition has intensified as newcomers challenge the established major airlines. In 1978 the average total cost per available passenger seat mile was less than 7 cents. Today, a conservative estimate is that this figure will be over 16 cents by 1990.

The cost of fuel is taking an increasing proportion of the operating cost dollar for the airlines. Based upon reported data, in 1973 the cost of fuel was about 10 percent of total operating costs. Even with the efficiency and load factor improvements we have seen since then, this figure has risen to the point that when jet fuel prices reach $1.00 per gallon--which is not hard to imagine--it will drive fuel costs up to more than 30 percent of total operating costs.

General aviation faces a twofold problem with respect to aviation gasoline, part of which has been discussed today--cost and availability. In June 1980 the national average selling price for aviation gasoline was around $1.65 per gallon. This is a large out-of-pocket expense for many general aviation operators, but the problem of high fuel costs is shared by the airlines, commuters, and general aviation alike. The special problem faced by general aviation is the availability of aviation gasoline. Spot shortages at airports can be expected, and, in fact, some spot shortages and troubles with deliveries have already been reported to us. I am interested in this problem and have personally visited with some managers of refineries who discussed the problem of small lot production mentioned earlier. This is going to be an increasing problem for general aviation operators.

As a military enthusiast and pilot, I believe we have a problem of perception among the nonflying public and, indeed, with those who fly only on airliners. As long as there remains the

perception of general aviation as an instrument of pleasure--and perhaps even conspicuous consumption--it will have problems in maintaining the political power to ensure its share of fuel supplies.

Thus, there is no question in my mind that we need aircraft that are more efficient. In an environment of increased competition, this need has become even more acute for the airlines. With operating costs rising faster than the airlines can cover them, earnings have suffered. You have already heard this problem discussed earlier today. These losses, which appear to have continued throughout the second quarter--although complete data are not yet available--impair the ability of the airlines to finance new equipment from internal sources. Furthermore, they weaken the competitive position of the airlines for obtaining external financing through the capital markets.

In the midst of this troublesome situation, it now appears that, based on a recent Air Transport Association study, upwards of $80 billion may be needed by the airlines over the next decade to finance new passenger aircraft. This increase in estimated capital needs is a result of several factors, including strong growth in passenger demand, higher than expected inflation, pressure to reduce noise levels, and, of course, rising operating costs. The question is whether sufficient capital will be available to meet these needs.

Earlier in this meeting we heard Fred Bradley document the sources of financing from which these capital funds must come. Viewing it somewhat differently--in economic terms--for at least a generation we have looked to economic growth and rising productivity to provide needed investment capital. In the future, rapid economic growth simply may not be available to produce major amounts of investment capital. If that is the case, rising productivity becomes an even more important source.

One of the functions of the API organization is to develop and publish the FAA's aviation activity forecasts. Our long-term forecasts support the need for new aircraft. Admittedly, the short-term outlook is for little or no increase in most activity levels until we begin to recover from the current recession. As a result, our most recent predictions reflect somewhat less growth for the decade ahead than the forecasts we published last year. We are predicting an overall 5 percent annual growth rate in passenger miles. That amounts to a 50 percent total increase by the end of the decade, with the 1980 activity remaining at about the 1979 level. We predict only a modest increase of about 20 percent in U.S. air carrier operations over that same period. This lower rate results from a continuing shift to larger passenger capacity for air carrier transport aircraft. On the other hand, we expect total air taxi and commuter operations to nearly double by 1990. This reflects the continued rapid growth in this area as air carriers restructure their routes. Commuter airlines are expected to move into the opening market opportunities on less dense routes, usually with more frequent schedules in smaller aircraft.

We expect general aviation itinerant operations to increase a total of about 44 percent over the next decade, which is a slightly higher rate than the 30-percent increase over the last decade. We are

predicting an approximately 63-percent increase to nearly 60 million hours for general aviation activity and an increase in the fleet of just over 100,000 aircraft. An interesting aspect of the forecast for general aviation is that we expect a larger share of the growth in the more sophisticated aircraft--the turboprops and jet aircraft. Their portion of the total flight hours is expected to grow from the current level of 9 percent to about 13 percent by 1990. Another interesting but not totally unexpected facet is that local and training flights appear to have been suppressed more than itinerant flights by the rapid fuel price increases. We also expect that high fuel prices will hold personal flying to a lower growth rate than business flying. In our forecasts military operations are expected to remain constant through 1990.

One segment of aviation with significant growth potential is rotorcraft. Our most recent forecast is for the United States civil fleet to increase from 5800 to 11,100 rotorcraft by 1992. That is a growth of 91 percent.

To summarize what our individual forecasts are saying, we expect aviation to continue to grow faster than the general economy, but at a slower rate than we predicted last year before the recession. In the commercial intercity passenger market, aviation has and will continue to be dominant. I see no fundamental change there. But commuter-type operations and, perhaps, business use of general aviation will show greater growth than the larger airlines and personal use of general aviation.

When we pull together all of these individual projections we see some trends emerging that may be at odds with each other. We see a steady growth in traffic demand placed upon the system. This demand will lead to more congestion in the system, particularly at the major hubs. On the other hand, we see rapidly rising operating costs--with soaring fuel costs as the major contributor--increasing the pressures for much more efficient aircraft and expeditious traffic movement. To deal effectively with this situation we will have to either make substantial capital investments in the national aviation system or face the possibility that constraints must be imposed.

It seems necessary to make one more comment on that idea. Both Secretary of Transportation Neil Goldschmidt and FAA Administrator Langhorne Bond have made statements about that, some of which I think may have been misinterpreted. The point is that, if we have growth and if we are not able to accommodate that growth through the capital investments needed to keep pace with it, then constraints might have to be imposed. No policy of constraining growth has been announced by either Secretary Goldschmidt or Administrator Bond.

Looking at the investment needs of the aviation system and the airline industry, it appears that there may be a shortfall of available capital over the coming decade. Looking to the international arena, we see our former position of leadership being challenged and eroded as competition becomes increasingly fierce. All in all, I believe you have to draw the conclusion that the 1980s will be an interesting decade.

What does all of this imply for the future direction of aeronauti-

cal research and development? I believe this outlook leads us to several areas of research and development that merit attention. Safety, of course, is our major concern. The greatest single cause of accidents in the system is human error. We need to know more about the human element in the system. We need to know more about the interfaces between the pilot and his aircraft, other aircraft in the system, and the traffic controller. And we need to know more about how the pilot himself deals with various situations. We must better understand the human element to be able to cope with, and hopefully prevent, the human error.

Fuel efficiency is another major area. We need more fuel efficient aircraft. We must develop more fuel efficient technologies in aircraft design, powerplants, and operating procedures. It seems likely that one of the major areas for research is that of operations. I think someone should be looking at alternative fuels for aviation. Since the fuel usage for all varieties of aviation is only about 4 percent of total domestic petroleum use, it is not a driving force in the marketplace. Therefore, I am tempted to ask: If NASA doesn't do this, who will?

Another area for attention is the emerging short haul, low density markets. The commuter airlines are moving into the market opportunities made available as the air carriers and local airlines restructure their routes. Since the commuter airlines generally use smaller aircraft than the air carriers and locals, there is a large market emerging for small transport aircraft--sort of a middle market between the general aviation aircraft and the large, high technology aircraft of the airlines. Although there is some activity in the area of 20- to 40-seat aircraft, I believe there is a need for better designs and more technology advances in both that range and the 60- to 120-seat range.

Overlaying all of these areas is the fundamental concern that we develop cost-affordable technologies. Increasing attention must be given to the ability of the government, the airlines, and the users to pay for improvements. Future aviation technologies must be developed with greater consideration for their acquisition and operating costs. In light of the vast long-term investment needs of the system, rapidly escalating operating costs, and the general mood of fiscal conservatism--none of which is likely, in my view, to disappear--we must put much greater emphasis on developing technologies that are efficient and affordable.

Thank you.

THE OUTLOOK FOR MILITARY AERONAUTICS

William J. Perry
Under Secretary of Defense for
Research and Engineering
Department of Defense

Guy, I want to thank you for inviting me here. You took quite a risk. You are going to get the perspective not from the point of view of an aeronautical engineer but from the viewpoint of somebody who is biased in electronics, which I am sure will be quite evident to you all before my talk is over. Aside from that bias I have resisted the temptation to give you a listing of programs that the Defense Department is doing or plans to do in aviation. Instead I will attempt to provide you with the perspective that underlies our planning, leading to the determination of our R&D programs as well as specific system developments.

The first and the most fundamental point, I believe, has to do with the broad strategy with which we approach our acquisition of new weapons systems. It is that we should exploit the technological superiority that the United States enjoys today to get a qualitative superiority in our weapons.

This has not always been the case. I would like to take you back a little bit in history to recall that the principle impact that the United States had in World War II--and in fact in World War I as well--resulted from our enormous logistics advantage. That is, we brought great fire power and logistics advantages to bear that had a decisive effect in both wars.

To illustrate that point, I note that the United States alone produced over 50,000 military aircraft in World War II. So, we mobilized our tremendous industrial base and brought it to bear on the problem. Whether or not our aircraft were superior to those of our opponents in World War II can still be debated, but it wasn't terribly relevant when we were building 50,000 of them. We overwhelmed them with numbers.

Today--for better or worse--the shoe is on the other foot. Any

planning that we do must start with the recognition that it is on the other foot. To give you one figure to illustrate this point--in the last 10 years (during the decade of the 1970s) the Soviet Union invested about $240 billion more in military equipment than the United States. That figure may be 10 or 20 or 30 percent off, but despite this uncertainty, it is clear that we are facing an enormous problem and an enormous disparity in numbers.

We see the problem manifested in the current and recent production rates in the Soviet Union. We see tanks that are being produced at three times the rate at which we produce tanks; missiles at about three or four times the rate. Even in tactical aircraft, where we have traditionally had a numerical as well as a qualitative advantage, Soviet production has been twice that of the United States.

That is a fact, whether we like it or not. When we come up with our investment strategy we start off with that fact and decide what we should do about it.

Many people argue that we cannot depend on quality, that we have to somehow deal with that quantitative advantage directly; we have to compete in kind. Whatever you may think about that argument, it is not possible for us to do it, at least it is not possible in our lifetime to do it. The momentum behind the Soviet production advantage and the deployment advantage is just too great. If we decided today, for example, to triple our tank production--which is a pretty big decision to make--and if the Soviets stopped their tank production--just turned off the valve altogether--it would be 1995 before we would have as many tanks as they have. So, that is the kind of problem we are facing.

I would further point out that, if I could snap my fingers and have Chrysler or General Motors deliver to our door next week 30,000 tanks, so that we now had as many tanks as the Soviet Union, then the questions we would face are: What do we do with these tanks? How do we man them? That is 30,000 times four people in a tank, times the cooks and the bakers and the recruiting sergeants and all the other people. It would mean doubling the size of our peacetime army.

So, unless you are willing to assume that we have three or four years to mobilize for a war--which we do not assume from a defense planning point of view--we have to figure out some way of dealing with this problem that does not involve doubling the size of our army. That means having a real qualitative edge; an edge that isn't just something that appears in the specifications of the equipment, but an edge that makes a difference in combat performance.

With that background, let me look at some of the specific objectives we have in the Defense Department and see how we will achieve them, how we might seek that kind of advantage, and the particular means we will employ to achieve it in combat performance.

One of the most obvious and certainly the highest priority requirement that we face in the Defense Department is deterring nuclear war. I can translate that into saying that we want to be able to maintain the unquestionable ability to retaliate in the face of a surprise attack.

We have sufficient forces to do that today. All of the strategic

forces programs that are conceived or planned for the next decade are designed to maintain that situation by improving the survivability of our forces. Very little of what we are doing is oriented toward improving their performance or improving their striking power. The entire thrust of our strategic forces' modernization program involves actions to improve survivability, that is, improve the ability of our retaliatory forces to survive a surprise attack.

I don't plan to discuss strategic forces today, but let me just tick off very quickly the three major programs under way.

The MX missile program is not so much a missile program as it is a program to provide a survivable basing for missiles. The cruise missile program is not so much oriented toward improving the striking power of our bombers as it is to allow our bombers to perform their mission without having to enter the air defense net of the Soviet Union. If our bombers were required to penetrate Soviet defenses, we think they would not be able to survive in the mid- to late 1980's. The new Trident program, both the submarine and the missiles, is also designed to improve survivability. The submarine is designed to be many decibels quieter than the existing Poseidon submarines, which makes it harder to find at sea. The missiles are designed to have twice the range of the Poseidon missiles, which allows the submarines to stand back farther from the shores of the Soviet Union, thereby increasing their available patrol area and their survivability.

All of these programs are pointed toward increased survivability. In my view, the heydays of the aviation industry's role in the strategic forces--which was building planes that could fly faster and higher and so on--are really behind us. Even though we are confident we could do that, there is little motivation to improve our forces along those lines.

Our second major objective is to deter the outbreak in Europe of what is called a conventional war; by a conventional war, we mean a recreation of the Second World War in modern times. We imagine that the Soviets' view of that is that if a war were to start they would mount a blitzkrieg heading for the Channel; you might imagine it to be the reverse of the blitzkrieg that Hitler launched against them--Operation Barbarossa--back in 1940.

So, if we want to deter that action from a military point of view, we should improve our ability to stop a massive armored attack. There are two different things that we are doing in our defense program that relate to that. One of them is making really major--I would say revolutionary--improvements in our antiarmor capability. I ordinarily would describe this in terms of what we call precision-guided munitions, and that is an interesting subject for a different day. It is also quite true that the carriers of these precision-guided munitions become quite important and, thinking of Gerry Tobias' talk a little bit earlier, helicopters are going to play a major role in our antiarmor capability.

The second action in stopping the blitzkrieg is maintaining air superiority. We believe we have today the capability of controlling the skies over Europe if we were to be engaged in a war with the Soviets. We believe it is going to be difficult to maintain that in

the future but that we can do it. As long as we can do that, and as long as the Soviets realize we can do that, we do not think they would be so foolish as to launch a blitzkrieg attack on Europe. One would have to be the world's greatest optimist to believe that he could sustain a massive armored assault in the face of air inferiority, in the face of the other side having control of the skies. I will come back to the point of air superiority in a few minutes because I would like to make that a major theme.

I do want to cite a third major objective of the Defense Department. I have described deterring nuclear war. I have described deterring conventional war in Europe. A third one is deterring a Soviet intervention in a conflict in the Persian Gulf or Indian Ocean area. We believe that in order to do that we have to develop an ability to quickly introduce intervention forces in that area. By quickly, I mean in a matter of a few days, soon enough to arrive before the disaster has happened, not after.

We believe that if we have the ability to do that, then it will provide a major deterrent to ever having to use that capability.

In order to be able to achieve that, we need to be able to maintain the sea power advantage we already have in the Indian Ocean. We need to pre-position heavy equipment in that area. That is already under way. We have equipment for an entire Marine amphibious brigade being loaded on ships on the way to Diego Garcia this summer. But we also need to make significant improvements in our airlift capability, particularly the ability to airlift what we call our equipment. That requirement is the genesis of what is called the CX program, and that will be one of our major aviation needs for the next few decades.

Let me come back to the point of air superiority. It is going to be difficult to achieve. I have already mentioned that the Soviets are building about twice the number of tactical aircraft that we are. What is perhaps of even greater concern is they are building aircraft of greater and greater capability. The qualitative gap between U.S. tactical aircraft and Soviet aircraft is narrowing each year.

They have, today, the MIG 23 and MIG 25, the so-called "Flogger" and "Foxbat" aircraft--very capable and very sophisticated aircraft. There is a widespread myth that the United States builds expensive airplanes and the Soviet Union builds simple, reliable, and cheap airplanes; that is no longer true. For better or worse, they have emulated us in this department and they are now building aircraft as complex and as expensive as ours. That is certainly true with the MIG 23, and we believe it is true to a certain extent with the MIG 25, certainly with the modified MIG 25, "Foxbat."

In addition to that, we know that they have a new technical combat aircraft in a very advanced state of development and expect them to be coming into operation by the mid 1980s.

The question then is, in the face of this very determined thrust both in quantity and in quality, how are we going to maintain the qualitative edge? I suggest to you that it is probably not going to come from the design of the airplane. That is not to say that we are not interested in the design of the airplane. We are interested in aerodynamics, but we don't believe that that is going to give us a

sufficient edge to deal with the problems that we would face in providing and achieving air superiority in Europe during the 1980s. We think it is going to depend on superior electronics, superior engines, and superior pilots. That is what the qualitative edge will depend on for the next decade or two.

Let me be a little more specific about how those different features will be manifested in our systems. We conduct analyses of air-to-air combat situations, in particular, the very detailed simulated combat we conduct at Nellis Air Force Base in a program called "Red Flag." In this program, we bring in squadrons of U.S. tactical fighters and match them against an aggressor fighter squadron that we keep based there. The aggressor fighter squadron employs U.S. airplanes, F-5s, which we think are somewhat of an approximation to the capability of the Soviet airplanes that we might be up against. We have a set of pilots who live, breathe, and act as though they were Soviet pilots month after month. So, we bring our fighter pilots in and we conduct simulated air combat. It is about as close to the real thing as you can get.

What we are learning in this simulated combat is that, while the quality of our airplanes, the F-15 and F-16, is noticeable and while they give us somewhat of an edge, it is not enough of an edge to offset a substantial advantage in numbers, even a two-to-one advantage in numbers. Therefore, if we are to prevail in a situation where we might have a two- or three-to-one disadvantage in numbers, we have to have something else going for us. That something else, we believe, will come from our superior electronics.

First of all, if our pilots, if our fighter squadrons, have superior knowledge at all times of the location of enemy airplanes then that can be used in a fundamental way to offset the disadvantage in numbers. That is, even though they may have a macroscopic advantage in numbers, we can achieve a microscopic advantage. We can arrange to have our airplanes at locations where we outnumber them at that time and at that place.

We can do this by having superior means of locating enemy forces, superior means of locating our own forces, and superior means of rapidly communicating this information around to all of the people involved in that operation. That is done, by the way, with a system that is called AWACS, which is a large, flying radar; with a system called GPS (Global Positioning System), which locates our own units to within 10 meters at all times; and with a system called JTIDS (Joint Tactical Information Distribution System), which transmits digits from reconnaissance systems to AWACS airplanes to fighter airplanes, so that the fighter pilot has at all times displayed in front of him what in effect is a situation map. It tells him where enemy pilots and friendly pilots are relative to where he is. That information is continuously upgraded and displayed in front of him. That, we believe, will make an enormous difference.

The second aspect where electronics will make a big difference is in the kind of munitions that we use on the airplane. In the case of air-to-air combat, the air-to-air missile is the principal weapon that can make the difference.

We are now developing a missile called AMRAAM (Advanced Medium-Range Air-to-Air Missile), which will have an enormous advantage over most existing missiles; it has a fire-and-forget capability. That is, the pilot can fire it and then he can turn and break away from the combat. The missile then proceeds autonomously to perform its mission. Moreover, he can fire two or three or four of them simultaneously. That is, he can engage several targets at a time and still break away. This is going to be extremely important in his ability to deal with situations in which he is outnumbered.

Those are the two principal factors in electronics that will make a difference. There will be very important improvements, I believe, that will be made in what we call RAM-D, what Gerry referred to as the reliability and maintainability areas. Most of these are going to occur through major improvements in jet engines in the next decade, through the introduction of super alloys into these engines which have the ability to withstand higher operating temperatures, with much greater durability. Therefore, we will be able to operate them at suitable performance levels well below the peak temperature of the materials.

As it stands today, with the F-100 engine, for example, which is the key engine we use in both the F-15 and the F-16 airplanes, we operate it so hot to get the performance out of it that we have a serious impact on its maintainability and durability. We would like to get that performance without being so close to the razor's edge. The way we do that is by employing super-alloy techniques for improving the temperature and durability of the turbine blades and other components in the hot section of the engine.

Two final points. First, training. I have mentioned the superiority of the pilots. That superiority will be achieved only if we can maintain adequate training for them. It gets more and more difficult to achieve that training through flying airplanes many hours per month. Some of that has to be done. We would like, for a variety of reasons, to minimize it. Also, no matter how many hours you fly per month, it is not the same thing as training for combat. Both of those factors drive us into developing higher and higher fidelity simulations.

Those of you who have followed this field know there have been very dramatic improvements in simulation in the last five or six years. We intend to push those technologies very hard. So, we are converging toward a situation in which a pilot can not only get training on how to land an airplane, but actually on how to simulate the conditions of air-to-air combat with the pilot sitting on the ground, including the visual, audio, and the motion sensations that go with it. We are much closer to that than you would think if you are not working in this field.

My second point is with regard to improving the survivability of our airplanes. There will be two fairly unromantic and undramatic technical thrusts in that direction. We will be converging toward having a greater short takeoff and landing capability in our tactical airplanes. This will allow our airplanes to survive better in an environment where airfields are major targets.

Also, we are working hard and will continue to work hard to introduce the technology of low dectectability in our airplanes. Our airplanes today are very good targets both for radars and for infrared sensors. We know how to make dramatic improvements in both of these respects. We know how to greatly reduce radar cross section. We know how to greatly reduce infrared emissions. Every time we have come down to actually designing an airplane in the last few decades we have looked at that trade-off and decided that it just wasn't worth the performance loss to achieve the survivability gain.

Two things have happened that will cause us to make different judgments in future designs. First, the air-to-air missiles are getting very, very good. An AMRAAM missile, the one I described to you, this radar-guided missile, is a very formidable threat to an airplane today, in no way to be compared with the threat of a Sparrow missile in the Vietnam War era. The A-9M, which is the current design of the Sidewinder missile, is vastly superior to the Sidewinder when it was originally developed.

Therefore, in order for an airplane to survive, it will have to pay attention to ways of defeating those missiles. It will not be able to defeat them solely by maneuvering. The pilot will not be able to defeat them by being a "hot" pilot or having a "hot" airplane. There have to be ways, somehow, of directly defeating those missiles. We will exploit countermeasures and jamming to get as much mileage as we can. But, all of those tactics become much easier if you have reduced your size as a target to begin with. So, we will have a very great emphasis on that in the future. I think all future designs of tactical airplanes will manifest those technologies to the extent that they can.

The bottom line I would give you on air superiority is that we will be able to maintain it. But, we will not be able to maintain it with a silk scarf mentality. We will have to maintain it by using the technology that we have, by putting a heavy emphasis on weapons that go with the airplane, putting a heavy emphasis on helping the pilot know what the situation is at all times, and by training the pilot through simulation. That will be our major thrust in the 1980s, rather than, speaking in relative terms now, getting the last 10 percent of performance out of the airplane itself.

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THE OUTLOOK FOR FUTURE DEVELOPMENTS IN
TRANSPORT AIRCRAFT

T. A. Wilson
Chairman
The Boeing Company

Gentlemen, I have been asked to discuss the outlook for continued U.S. transport aircraft leadership during the next decade and the importance of maintaining our nation's preeminent position in the world's commercial jet transport market. Before doing this I intend to generalize a bit on the U.S. economy and certain government practices and policies. Then, I will narrow down on some specifics.

The U.S. aerospace business is in relatively better shape than the rest of the nation's industry. That is a new role for aerospace and we shouldn't take too much comfort in it. One industry cannot keep succeeding while all about it others are failing. Everything affects everything else.

Aerospace is one of the few preeminent industries we have left. The other industrialized powers are placing greater emphasis on their aerospace development. I suppose being number one is more important in some fields than in others, but if various U.S. industries were to follow one another down an economic toboggan slide to become also-rans, the cumulative effect for the nation will be disastrous. We risk not only our standard of living, but our national security as well.

I think the outlook for continued U.S. leadership in transport aircraft is promising if the industry is permitted to operate in a supportive economic and political environment. We need an environment that encourages growth, not misguided policies that strangle it. Unfortunately, in this regard, we have developed a bad habit of shooting ourselves in the foot. I will have more to say about that directly.

Admittedly, as we enter the 1980s we see that it is a far different world than it was when the 1970s began. The energy situation, or at least our perception of it, has flip-flopped during the past 10 years. About half the oil currently consumed by the U.S. is imported and subject to sudden price increases or supply cutoffs. It is easy to blame the cost of oil imports for most of our economic problems, but it is not that simple. Germany and Japan import essentially all of their oil but their economies

remain strong and stable. The problems of the U.S. economy are rooted in several areas, including a tax policy that is biased against savings and investment and a myriad of regulatory policies that have stifled trade, productivity, and job opportunities for millions of Americans.

It is essential that we adopt a long-range program on a national scale to remove the basic causes of some of these problems rather than deal with their effects. We need some preventive medicine for our economic ills instead of haphazard emergency service that may or may not save the system.

Since the late 1960s the U.S. economy has steadily gone downhill in comparison with major industrial powers such as Japan and Germany. During the 1970s the U.S. lost about 23 percent of its share of world trade, amounting to some $125 billion and at least two million jobs.

Our military situation has deteriorated along with our economic decline. Even though the fiscal 1981 defense budget has increased considerably over that of recent years, it still represents a smaller portion of national expenditures than it did in pre-Vietnam days. In 1960, for example, the defense budget accounted for 9.3 percent of the gross national product (GNP). The current budget request will take 5.2 percent of the GNP, and the plan is to remain at about that level through the mid-1980s.

Meanwhile, comparing our defense spending with that of the Soviet Union, you find that the Soviets exceeded our military spending by about 30 percent during the past decade. Military experts believe the Soviets are currently spending 40 percent more than we are on defense. From a position of military inferiority 10 years ago, they have now at least achieved equality and perhaps reached a position of superior military strength. They have more planes, more tanks, more guns, and more missiles than we do. And our once-flaunted technological advantage in military hardware has just about disappeared.

This is not my charter for discussion today, but I feel this is an area of extreme importance for our nation. I think that we are in deep trouble and if we do not maintain a strong, credible military establishment equipped with the most advanced weapons systems we are capable of producing, there is no point in worrying about the future of transport aircraft or any other U.S. industry. We will all be losers.

The energy outlook is equally bleak and won't get better very soon. Although we have the capability and the resources to make big improvements, what we seem to lack is the will to do anything meaningful. For six years we have stumbled around trying to establish an energy policy, and we still do not know where we are going.

The energy situation is a classic example of knee-jerk responses to a serious problem and government confusion at worst.

As the cost of OPEC oil rose, the government continued to keep domestic oil prices far below world levels, allowed U.S. imports to double, and then unleashed its bureaucratic militia to guide the energy hunters on their way. The Energy Department pressured companies to switch from imported oil to coal, but the Environmental Protection Agency issued more stringent air pollution controls that knocked coal out of the picture.

One agency encouraged offshore drilling to find new oil deposits, while another moved to block such efforts.

Foreign trade is another area where we are in some trouble and could be

in more if we don't straighten up and fly right. Several critical issues underlie our foreign trade problems, including government action or inaction, taxing policies, inadequate research and development support, and regulatory activities. I will comment on each of these in a few minutes, but all of them have a common thread--adversarial relationships.

In 1971 the U.S. experienced its first negative balance of trade in this century. Since then we have suffered billions of dollars in deficits every year except 1973 and 1975. During this decade of deficits, most high-technology industries in the U.S. maintained a positive trade balance and aerospace led the list among manufactured products.

In 1979 the positive balance of trade for aerospace products exceeded $10 billion, with commercial jet transports accounting for most of that. These foreign commercial jet transport sales provided jobs for well over half a million Americans. The U.S. has established a dominant position in the world's commercial jet transport market, but foreign competition is growing.

European aerospace industry increased its sales from $4 billion in 1970 to $6.3 billion in 1977, while U.S. sales actually dropped from $22.3 to $19 billion in constant 1970 dollars. European sales amounted to 19 percent of U.S. sales in 1970, but rose to 33 percent of U.S. sales in 1977.

Last year, Airbus Industry, the European consortium, captured about 30 percent of the new orders for commercial jet transports with its A-300 family, more than McDonnell-Douglas and Lockheed combined. We credit some of this success to favorable financing arrangements by the governments that own Airbus Industry, but we also recognize that Airbus is a formidable competitor reflecting a very solid base of technological development.

Among the major trading nations of the world, only the U.S. seems to regard foreign trade as a sideline activity, which is largely ignored as an economic base for domestic prosperity and jobs but frequently used to deny sales to some country in an attempt to infuence its actions. Sometimes we seem to invoke sanctions just because we don't like the particular country. Then, a few years later we change our mind.

In addition, we insist that other nations observe our standards for human rights and environmental regulations if they wish to buy our products, as if the U.S. were the only source for such goods throughout the world. U.S. morality has become a major export. Although this sort of pressure seldom has any effect except to eliminate sales and therefore jobs for U.S. firms, it continues to be a popular exercise in futility.

Except for the Export-Import Bank we have found that most U.S. government activity related to foreign trade has to do with restrictions and prohibitions. In recent months the Export-Import Bank has come under attack, apparently because it has done an excellent job of providing financing to foreign buyers of U.S. products, including large numbers of transport aircraft. They had the failure of being successful, as Art Buchwald would say.

Most other nations actively support their export trade, with the Japanese probably the most proficient. The recent report by Japan's Ministry of International Trade and Industry (MITI) outlined the steps necessary for continued industrial expansion during the balance of this decade. This report represented the cooperative efforts of ministry officials, industrialists, labor union leaders, and members of the Japanese

consumer groups. The Japanese are strong believers in research and development. The MITI report stresses the crucial role of technological development and recommends that the ratio of technology spending to gross national product be increased from the present 1.7 percent to 3 percent by 1990.

Total R&D support by the U.S. government has averaged about 1.2 percent of the GNP over the past five years. Incidentally, the Japanese are placing a priority emphasis on their aerospace sector and, in particular, on the energy-efficient aspects of their aerospace technology.

The Japanese government favors active support of corporations trying to achieve technological breakthroughs that contribute to these objectives. Obviously, the industrial policy of the Japanese is quite different from the government-business interface, but they do encourage expansion and have become highly competitive in the world's marketplace.

Without advanced products that meet customers' needs it doesn't matter how benign the trading atmosphere is. Advanced products depend on a progressive and timely research and development program to produce the technology. Here, too, the U.S. has been flunking the course in many respects. Last year about 50 percent of all research and development funding was provided by the government. That may sound impressive, but in the early 1960s it was about 65 percent. During the 1970s, federal R&D funding declined about 9 percent over the previous decade. Contrary to what most people believe, defense R&D has actually decreased 17 percent during the past 10 years, and the space effort R&D is about half what it was during the 1960s.

Viewed as a percentage of the GNP, total government funding for R&D during the 1970s is down 34 percent from the previous decade, while defense R&D has dropped about 38 percent.

To a large extent we have been living off the aeronautical research dividends of the 1950s and 1960s. Much of that research was funded by the government for military and space programs. No one would deny that the U.S. commercial jet transports owe much of their success to the pioneering work done on military programs such as the B-47 and the B-52. I also trust that no one would question the tremendous payoffs in commercial and social progress as a result of the jet airliners. At one time the benefits of military R&D flowed into the commercial sector. That flow has been reversed in recent years. In addition, the U.S. Air Force now has jet tankers, airborne command posts, flying navigator trainers, and airborne warning and control systems in inventory. All were based on commercial platforms that have been modified for military requirements.

We seem to have a big problem with subsidies these days. We don't know how to define them or whether they are good or bad. In fact, we can't walk across the street, have dinner, or take an airplane trip anywhere without running into a number of subsidies, most considered good. There are subsidies for highways, agricultural products, airports, FAA controllers, and the weather bureau, to mention a few.

It bothers me, however, when an important part of the NASA budget for aeronautical research is called a subsidy that we don't need, or a bad subsidy that is unnecessary because it contributes to commercial technology development. I would call it stimulation--stimulation to preserve American jobs.

For many years the research efforts of NASA have benefitted the aerospace industry and society in general. Boeing has accumulated many years of experience working with NASA and with the Federal Aviation Administration on various aerospace problems. Our relationship with both these federal agencies has always been one of mutual respect. We may at times have disagreed on methods, but seldom on objectives. NASA's pioneering work has been valuable to Boeing even when we didn't use its specific development. For example, we developed our own proprietary airfoil for the new 757 and 767 aircraft, but NASA's technical data on the supercritical wing supported the validity of our work.

More recently, the industry has needed to respond in a very serious way to the fuel crisis and the consequent need for more fuel-efficient aircraft. We have had to investigate all the system elements: aerodynamics, propulsion, structures, and flight management--to name a few. NASA's work has been of great value to all three of the major U.S. commercial manufacturers. The most important element was that such work had been a continuous effort and as such was available to industry when the need arose unexpectedly, as it did in the mid-1970s.

Two of the many programs that provided the most benefit were the composite structures programs for more efficient aircraft structures and the advanced flight management program for more efficient aircraft operations. Both began in the early 1970s, and both represented cooperative government-industry efforts. Both were programs requiring such long lead times that evolution by industry alone would have been delayed or even unlikely. In our own case the results of these two programs have made our recent new programs, the 757 and 767, more competitive in the world market and, we hope, retained some American jobs that might otherwise have been lost to foreign manufacturers.

These two R&D programs are examples, I wanted to underscore, of the synergistic effects of industry and government working together to achieve a greater result than either could achieve alone. However, there are many other examples, such as winglets currently flying on test aircraft, the development of sophisticated area rule techniques to optimize drag, and active control systems that will eventually reduce weight and drag both by modifying structural loads and by reducing empennage size.

In some of these cases our proud Boeing engineers think they did a number of these things by themselves, but the NASA work helped show us the way. The agency prods the industry into doing things better and I appreciate that.

When government agencies or private firms in the aerospace family run into technical problems they go to NASA for help with the solutions. They usually find them because the agency has a significant technological capability. The relationship works, and when a government-industry relationship works you shouldn't try to change it. It is a rarity in my experience.

Let me talk about the future. Improved fuel efficiency will continue to be an imperative, and international competition will get progressively more severe. We can see potential efficiency improvement of some 25 to 40 percent, but we know the time and effort required to get it will tax the resources of government and industry working together. We know that in some cases our foreign competitors have more complete research and development

programs in place. Examples of advanced technology not matched in the United States include the work in composites for primary wing structure by Dassault of France and the shadow mask cathode ray tube development by Mitsubishi of Japan.

U.S. technology is dropping behind that of both the French and the Japanese in these critical areas and will never catch up at its current rate of progress.

It doesn't take much imagination to evaluate the situation as a serious one. The real American requirement is that we run faster, and that takes all the resources we can collectively assemble.

In summary, we need to address several key issues if we are to maintain our position of leadership in aerospace. We need a long-range policy on foreign trade, one that recognizes the overall benefit of exports for our national economy and American jobs. Sometimes the question of affordability clouds the issue. We need a strong, viable Export-Import Bank if we intend to compete in world markets. We need to increase, not reduce, our government investment in research and development from the theoretical beginnings through technology credibility attainment. We should develop a different approach to what is necessary to protect our industries. We need to shuck our national guilt complex about helping industry before it gets into trouble. We seem to have no difficulty in helping the losers, but the approach for sustained preeminence would create the conditions that make it possible for industry to grow. We need to exchange our savior policy for a winner policy. Stimulation is a lot more fun than rescue and a damn sight cheaper as well.

What seems obvious to me is that we must get our act together in the areas of foreign trade, research and development, and government-industry cooperation. At present, the United States is the leader in commercial jet transport development, but there are plenty of warning signs showing up. The situation is a world situation, and it has military as well as commercial overtones. Unlike the cooperative industrial programs developed by Japan and the European nations, the U.S. has adopted policies of confrontation in many areas. Such policies exhaust our energies and splinter our resources into nonproductive avenues.

In the government contracts area, far too much industry and government money is spent in monitoring and validating research work. The administrative expenses of some government contracting have reduced the productive value of the contract dollar by about half.

Our nation must begin to see the big picture, realize the benefits for all Americans of saner government-industry relationships and the absolute necessity for maximum research and development if we are to compete in today's world. The penalty of failure in terms of the economy, the balance of trade, and, most of all, American jobs is so serious that success is not just an objective, it is mandatory.

Thank you.

THE OUTLOOK FOR GENERAL AVIATION

Malcolm S. Harned
Senior Vice President, Technology
Cessna Aircraft Company

I will start by defining general aviation, because there seems to be a perception problem as far as this part of the business is concerned. It is defined as all aviation except military and air carrier. Consequently, it includes personal, sport, training, agricultural, air taxi, and business flying.

For many years business flying has been the dominant portion of the field. Currently, the domestic fleet consists of 184,000 aircraft, of which 2600 are jets, 3300 turboprops, 23,000 piston twins, and 155,000 piston singles. The international fleet is just about half again as large.

In the U.S., general aviation is currently providing about 15 to 20 billion passenger miles of premium transportation per year. That is about an order of magnitude less than the revenue passenger miles of the commercial airlines. However, general aviation is probably providing more essential passenger miles per year than the commercial airlines. Furthermore, this business transportation is vital to our economy and can only be supplied by general aviation. This condition has been brought about principally by the decentralization of industry and the move to get out of the overcrowded, unmanageable major cities. This trend of moving industry into large numbers of small communities will continue to expand the need for business aviation well into the future.

The airline deregulation law and high fuel costs have combined to force the airlines to become extremely efficient transporters of masses of people over long distances. The reductions in air fares have generally caused large increases in traffic, crowded airplanes, and congested terminals. These factors make flying very unpleasant for the businessman and eliminate the possibility of working while traveling.

In addition, as a result of the quadrupling of the costs of avia-

tion fuel, the airlines can no longer afford to service their low load factor routes, which generally are to decentralized, industrial communities. For a few statistics--of the country's 15,000 airports, less than 350 are served by the airlines. About 70 percent of all passengers emplane at the 25 major hub airports, with one-third emplaning at the top 5. Also, in the last 20 years airline service has been discontinued to over one-third of the cities once served by the airlines.

Another condition that has built business aviation is the high load factor necessary to conserve fuel and achieve low airline fares. High load factors frequently mean leaving people at the gate. Since the businessman tries to minimize his time expenditure, he is most likely to be the last at the gate and the one to be left. After missing a couple of important business commitments, a corporate aircraft becomes a real necessity.

Without the business aircraft we have had, our rapid industrial expansion of the past 30 years would have been completely impossible. In the future, they will be even more essential.

Another service offered by general aviation is the air taxi or commuter aircraft. Reductions in service to smaller communities on the part of the airlines has created a large demand for this commuter service from the many business people and others who need it but either cannot afford or cannot justify aircraft ownership.

Airline transportation on the long routes is one of the best bargains available today and will be even better in the future. In small communities there are large numbers of people who want to take advantage of the low cost, high speed air travel available at the major hubs, and this has created a very large demand for commuter operations.

Agricultural aircraft have become a necessary tool in the supply of food for the world. There are roughly 10,000 such airplanes treating one-quarter billion acres per year. For example, the U.S. produces the world's lowest cost rice by using aircraft to prepare the soil, seed, fertilize, weed, and protect from pests--all from the air. The only time farmers set foot in the rice fields is for the harvest.

Another essential service is that of training new pilots for all flying purposes. Over 50,000 new pilots enter aviation each year from the general aviation training services. Also of importance are public services such as air ambulance and law enforcement.

In addition to these essential transportation roles, general aviation has become a very significant factor in our economy. Figure 1 shows the growth in general aviation both in total airplane sales and in exports over the last 10 years. It has grown to 2.1 billion in gross airplane sales, with a $600 million export sales picture in 1979. That means that it has become a very significant business and plays an important role in our balance of trade. This is a business that if properly supported could grow even faster in the future.

To give a more complete perspective of what general aviation has been doing the past 10 years, I have three figures that show the relative position as compared to the other categories of aviation.

Figure 2 is a comparison of sales of general aviation (GA) aircraft to military sales. The abscissa is the percentage of GA to military. You will note that in the past 10 years the gross sales have grown from 5 to 15 percent of the military sales. Most significantly, the export sales have grown from about 15 to over 50 percent of the sales level of military aircraft. Also important is the fact that these are true export sales. They are not government giveaways.

The relationship to helicopter sales is shown in Figure 3. There has not been a very big change over the years; however, the fact that total sales are some 500 percent greater and export sales are about 300 percent greater gives a good idea of their relative economic importance.

Figure 4 considers transport sales. We all recognize that commercial transports are one of this country's greatest assets in our balance of trade battle. Therefore, it is significant that general aviation sales relative to commercial transport sales have grown from about 12 to better than 25 percent. (One year we hit close to 50 percent.) On the export sales end of the business, we have gone from 5 to over 10 percent as much and a couple of years were better than 16 percent of the export sales of commercial transport.

In summary, general aviation not only performs a number of very essential transportation roles, but has also become a vital and growing factor in our economy. I would like to recall one of T. Wilson's comments about the fact that our government should be supporting the winners. General aviation is not only a winner today, but it has the potential of becoming a much bigger winner in the future, if the technology is provided.

Now, I would like to turn to what is needed in the general aviation field for this growth to continue. Safety is an area that needs some serious attention. It <u>has</u> received considerable public attention in the last year.

Table 1 shows safety statistics on the basis of fatalities per 100 million passenger miles and is representative of the experience of the 1970s. The airlines have set an amazing record of 0.04 fatalities per 100 million passenger miles. It is outstanding for all forms of transportation. In contrast, the overall general aviation average is about 16 per 100 million, or 400 times worse than the commercial airlines. Even the much maligned passenger car fatality rate, which has dropped considerably in recent years with the advent of lower speeds and the use of safety belts, only runs 1.4 and our general aviation rate is 10 times that.

Also included in Table 1 are three specific small aircraft models on which we have good statistics. The Cessna Skyhawks have run at a level of 7 fatalities per 100 million passenger miles, and they are clearly the most forgiving and easiest to fly of the small single-engine aircraft. They still have a rate of 7, mostly because they are used a lot in training. In the 421s, there is considerable professional pilot operation and the rate is down to 2. In the case of the Citations, where virtually all the piloting is professional, we are down to a rate of 0.4, which is the same as the airline rate of 10 years ago. I cannot put too much emphasis on this question of pilot

proficiency.

Figure 5 also indicates the importance of that proficiency. Here, we consider Cessna fleet experience over a 10-year period. The reason I show this is because it tells the impact of the biennial review instituted by the FAA. You will notice that fatalities increased as the fleet increased in size. The moment that the biennial review was instituted the fatalities dropped essentially in half.

We must reduce the requirements for piloting expertise. Our airplanes, in the future, must be more forgiving, easier to fly, and better capable of coping with the environment so that proficiency is easier to achieve and maintain.

It is important to recognize the safety areas in most need of attention. Accident statistics show that approximately one-half of all fatalities occur during approach and landing; another 20 percent are associated with takeoff. So, essentially 70 percent occur during takeoff or landing and are related to stall speed. Consequently, we need to do everything possible to reduce stall speed. We also need to eliminate the stall-spin accidents by making the airplane stallproof. It is also important to offer better ability for coping with the weather at a much lower cost, since about 20 percent of our accidents are weather related. Pressurization, anti-icing systems, weather radar, and radar altimeters that can be afforded in all airplanes are essential.

In addition to the safety picture, there is also a big need for increased equipment reliability and a large reduction in maintenance requirements. Future customers will also insist on significantly improved comfort, primarily related to reduced noise and vibration levels. In addition, the requirement for good air-conditioning is going to exist in just about every airplane.

The overriding need for the future, however, will be improved fuel efficiency. With the anticipated higher prices, fuel costs will certainly dominate the cost of operation of all our aircraft.

Current fuel consumption status is illustrated in Table 2, in which statute miles per gallon (mpg) for an airplane and seat miles per gallon are presented. The numbers are good compared to the current American car and the current American airliner, which typically is a 50-seat-mile-per gallon airplane. However, they do not fare too well against the future 767s or 757s. We need to improve these numbers dramatically, and I think that with the technology promised it can be done.

There is a very great promise in this potential technology, most of which has already been identified by NASA. With this technology I think we have the makings for dramatically improving performance, fuel efficiency, and safety. Realizing that potential will depend on a greatly expanded NASA effort in general aviation.

Going back to the economic number I commented on earlier, we in the general aviation industry feel we have a stature today that says we have been seriously neglected in the share of NASA research.

The biggest single potential improvement that is offered by the new technology is in the field of composite materials (see Table 3). Most of you are familiar with the numbers, but here they are for

Kevlar and graphite. Both of these fibers, as you know, offer strength-weight ratios that are superior to aluminum. NASA's ACEE program has done an outstanding job of proving the suitability of graphite for use in airliners. However, before the potential is realized for general aviation a lot of developments are needed, including better approaches to lightning protection, new inspection and testing techniques, interfacing with metals, new approaches to structural analysis and design, new matrix materials (which is a particularly important area), new manufacturing techniques, and new methods for field repair. In addition, the material cost must be drastically reduced. However, if it is pursued properly, by the 1990s the problems can all be solved and the materials could be standard production items.

The fact that Kevlar, the aramid fiber, is replacing steel in premium tires today on a economically practical basis--it is essentially dollar for dollar right now--means that the potential for high volume, low-cost production of that material is promising. Consequently, we would expect it to become the general aviation structural material of the future.

These fibers, principally Kevlar with some graphite used, offer a real potential for reducing the weight of newly designed general aviation aircraft by 35 percent.

There should also be significant improvement in aerodynamic efficiency as a result of the universal application of refined versions of the NASA supercritical airfoil and the natural laminar flow airfoils.

Dramatic advances in electronic technology will continue in the future, thereby decreasing the size, weight, and cost of all avionics, as well as increasing capability and reliability. We fully expect this to come from the avionics industry. It is moving well today and we expect to see it continue.

Aircraft piston engines could be significantly better both in power-weight ratios and specific fuel consumption. Composite materials should be used extensively for weight reduction. Lean burning techniques with fuel injection and other improvements should also offer 10 to 15 percent reductions in specific fuel consumption. Even diesels could become usable with a 25 percent improvement in specific fuel consumption (SFC). Much more efficient turbochargers could contribute to improved SFC and power-weight ratios and will probably be used universally.

These are areas where NASA has started programs, all of which are very promising. The biggest question is whether these programs will continue to be implemented properly.

Turbo machinery should also be improved. Pressure ratios and compressor efficiencies have been limited in the small engines in the past because the sizes were too small to make use of highly efficient, axial flow compressors. However, today we see the way for development of centrifugal compressors that can be just about as efficient as the axials. This will permit the use of much higher pressure ratios and give greatly improved thermodynamic efficiencies. At the same time higher turbine inlet temperatures will be realized through such devel-

opments as monocrystalline metals and ceramics for turbine blades and stators. Here again, composite materials will be used to reduce weights.

Power-to-weight ratios could be increased by a factor of two. Specific fuel consumption should be improved by 25 percent in high-altitude operation. Here again NASA has made the start in these fields. The question is whether it will be followed up to achieve the potential result.

The use of pusher propellers should be made practical for the future as a result of using composites for lightweight blades plus helicopter technology providing the lightweight, reliable drive shafts and gear boxes. This approach offers significant drag reduction, because there is no propeller slipstream impinging either on the fuselage or on the cells. In fact, there is no need for nacelles to produce drag at all. This arrangement also provides reduced cabin noise and better visibility.

If developed on a timely basis these new technologies will generate many new airplanes that we expect will have the following common features and characteristics. All would be pressurized to provide the ability to fly over the weather and out of turbulence, with much greater efficiency and safety. All wings would have high aspect ratios of 9 or more. This would result in better climb, lower stall speeds, and better L/D ratios at high altitude. All would have full-span flaps with slot-lipped roll spoilers and flight path spoilers. The latter would be controlled by the throttle to provide negative thrust. All would have angle of attack sensors, limiting elevator power to keep the aircraft from stalling. This feature, combined with flight path spoilers, should completely eliminate the stall-spin accident. All would have advanced automatic flight control systems, the heart of which would be a central computer receiving information on all aircraft functions, including an air data system made possible by low-cost sensors.

All the navigation functions would be integrated with this, including DME (distance measuring equipment) and RNAV (radio navigation). The system would automatically calculate and fly optimum flight profiles. It would also eliminate the possibilities of disorientation and spiral dives. In many of the aircraft the system would be sufficiently redundant to offer automatic blind-landing capability at airports equipped with the necessary microwave systems.

Most would have engine monitoring systems sensing vibrations, torsional loading, and metal in the oil to anticipate engine failures well in advance. This would increase safety, reduce engine maintenance costs, and make the fuel-efficient single-engine aircraft very safe.

The six-place and larger airplanes would have strain gauge systems mounted on the landing gear that would provide an automatic weight and balance readout from the computer. All the airplanes would have radar altimeters, and most would have other radar. Most would have all-weather systems, including an anti-icing capability. Inspection periods would increase from 100 to 300 hours or once a year.

Now, I would like to examine a few examples of the aircraft that

these new technologies should make possible for the 1990s. The minimum four-place aircraft is depicted in Figure 6. It is essentially a very streamlined Skyhawk; however, it is supercharged and is pressurized to a 2.5 psi differential for cruising at 16,000 feet, which is above the worst weather problems, but still low enough to eliminate any concern over catastrophic decompressions. It also minimizes the weight penalty.

We would expect this new aircraft to be 25 percent lighter in empty weight than today's Skyhawk. The supercritical airfoil and the full-span flaps would combine to make reduction of the wing area by over one-third possible. However, the wing span has been retained in order to give good climb characteristics and a high L/D. The high-aspect ratio wing has a composite support strut with less than half the drag of today's struts.

This future Skyhawk would cruise at 185 miles per hour and offer a range of 900 miles under visual flight rules. At the same time it would cost less to buy, operate, and maintain (in constant dollars) than the Skyhawk of today.

Figure 7 exemplifies what could be a turbocharged diesel-powered four-place airplane. Because the engine is relatively heavy it is located in the nose with the propeller mounted on the tail. This provides an efficient aerodynamic configuration as well as a very low cabin sound level. The cabin would be pressurized to 4 psi, giving a 25,000-foot cruise altitude. The diesel would run at 3500 rpm with a light-weight drive shaft transmitting the power to a gear box at the rear, where the rpm of the prop would be cut to 2000. The drive shaft would pass through a center-tunnel armrest, as in a sports car. Wide chord composite propeller blades would provide good efficiencies at a high-altitude cruise.

Because of these capabilities, this airplane should cruise at 250 mph, have a 1600-mile range, and offer 26 mpg--a really high level of fuel efficiency, better than 100 seat miles to the gallon.

A minimum-cost twin-engine aircraft is shown in Figure 8. To provide a minimum cost, we have used two supercharged automotive Wankel engines. Their compact size and light weight make possible the convenient arrangement for the safety of center-line thrust. Since these engines are liquid cooled, the radiators would be the aluminum leading edges on the wing and on the tail surfaces. This would provide an automatic anti-icing capability. This would also be a 250-mph airplane cruising at 25,000 feet, but would only get about 18 mpg.

Although the Wankel engine will always be inferior to the piston engine in SFC, its lightweight, compact size, and lack of vibration will perpetuate its development as an automotive engine with the result that its low cost could make it very attractive for personal aircraft. The lack of a valve train and its basic simplicity should also make it very reliable.

Another new type of aircraft that we expect to be very popular in the 1990s is a single-engine turbopropeller type in a pusher configuration. This would be a six-place airplane, pressurized to 8 psi with a 400-mph cruise speed, and the ability to fly at altitudes

up to 40,000 feet. We would be looking at a turbo-shaft engine with 6000-rpm output reduced to 1800 for the propeller. The rear-mount engine and propeller will provide a very quite, smooth, cabin environment. It would have an 1800-mile range capability.

Because of the engine monitoring system it should be possible to virtually eliminate any concern over engine failure. This would offer a 16-mpg capability, again approximately 100 seat miles per gallon. This type of airplane will replace many of today's piston twins.

Another new category of aircraft for the future would be the twin-turbine single-propeller airplane shown in Figure 9. The two turbine engines, which have their inlets in the wing roots, would be geared together to drive the single propeller. In this way, you not only have two engines but also the safety of center-line thrust. Some people may object to the single propeller; however, people flying today in twin-engine helicopters depend on a single rotor to stay in the sky. This propeller would have a very high activity factor to drive the airplane at 450 mph at 45,000 feet, making it very comfortable and providing a cross-country nonstop range. It would have 8 to 10 seats and offer a fuel efficiency of better than 10 mpg; again, approximately 100 seat miles to the gallon.

Continuing on up the scale in speed in the 1990s, we should see a Mach 0.95 business jet, which is illustrated in Figure 10. This would offer a 20 percent increase in speed over today's business jets and, at the same time, provide high fuel efficiency. It would be necessary to bury the engines, "area rule" the fuselage, and go to highly swept wings with supercritical airfoils. We would also be looking at canards. The winglets in this case would serve the dual purpose of increasing aspect ratio and directional stabilizaion. You can see in this many NASA outputs, and we would expect to use even more.

This airplane would offer stand-up aisle height, 16 places, plus a 600-mph cruising speed at altitudes up to 60,000 feet, with ocean-crossing range. Even with this speed it should offer a fuel efficiency of better than 4 mpg.

It also offers the safety advantage of essentially having center-line thrust and would have a cabin that is free of engine noise.

Another important future category for general aviation will be short-haul commuter transport. This market will grow in size by many times in the next 15 to 20 years. Consequently, new designs will be developed in which the principal emphasis will be on the minimum amount of aircraft weight per passenger lifted into the air. One approach to such a 50-passenger machine is illustrated in Figure 11. By using a tandem wing configuration, minimum drag is achieved with good control power. This also makes possible an aft location of the turboprops to provide minimum cabin noise. It would be pressurized to cruise at 25,000 feet, where it would achieve speeds up to 300 miles an hour. Even for 100- to 200-mile routes it would offer over 100 seat miles per gallon.

In summary, in the 1990s the potential exists for general aviation aircraft to generally provide 25 percent more speed with 50 to 100 percent better fuel efficiency plus greatly improved safety, reliability, convenience, and comfort. The accident rate would be

reduced by well over an order of magnitude and it would be safer than cars. This should all come about if the new technology is developed on a timely basis, which will require substantial effort by NASA. In this way we would stay ahead of our foreign competitors and substantially increase the growth rate of general aviation.

A major concern today is the fact that there are 10 other countries already engaged in general aviation production and several others in the process of developing a general aviation industry. All of these governments are strongly supporting their industry by subsidizing R&D and tooling from 80 to 100 percent and, in many cases, subsidizing the manufacturing costs. On top of that they heavily subsidize marketing with low-interest, no-down-payment financing. Put together, this is a very serious threat, which in a five-year period could easily take the general aviation market away from the United States.

A very important aspect of the export market is the fact that in developing nations, where there are no railway or highway networks, general aviation aircraft can provide instant transportation systems with a very small capital investment. This creates a particularly good potential for rapid growth in this export market.

In closing, I would just like to make one comment on the importance of U.S. preeminence in aviation. Many, if not most, people throughout the world regard flying as man's most magnificent achievement. I think that is really true. It is not just this group here; I think it is true of people in general. This is borne out by the fact that most developing nations' first objectives after they develop any kind of economic stature is to have a national airline and then to have an air force. Not far beyond that comes having an aircraft industry.

In addition to the great economic importance that general aviation leadership offers, the continued position of preeminence in aviation manufacturing, we think, is the most important means for the U.S. to maintain its role of world leadership. Without preeminence in aviation, I think we can all be assured that we are going to be regarded as a second-rate nation throughout the world.

Thank you.

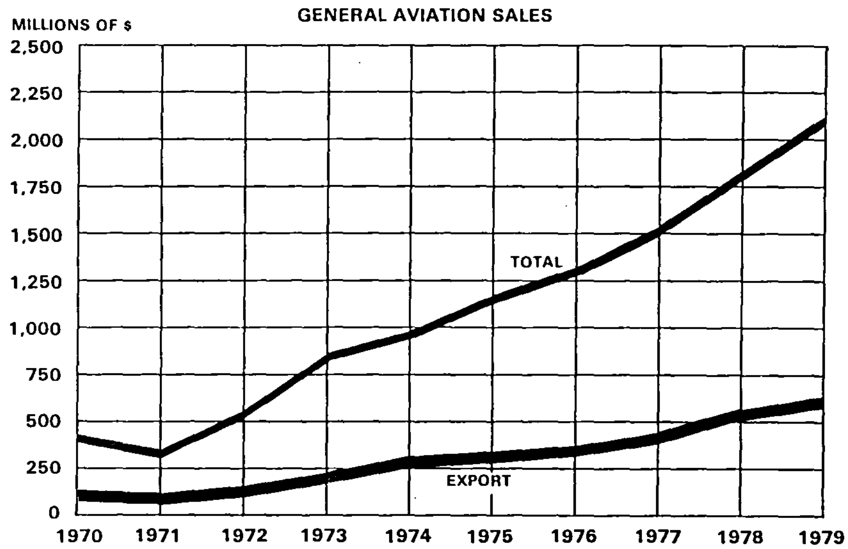


FIGURE 1

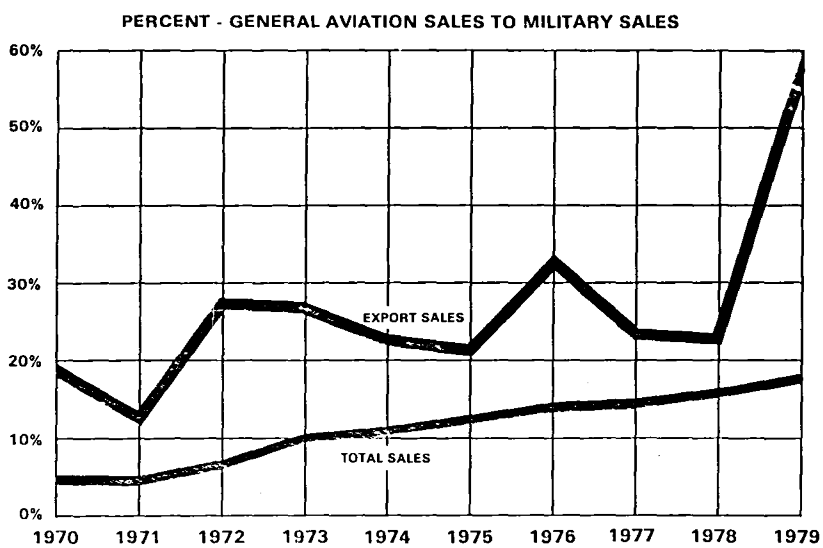


FIGURE 2

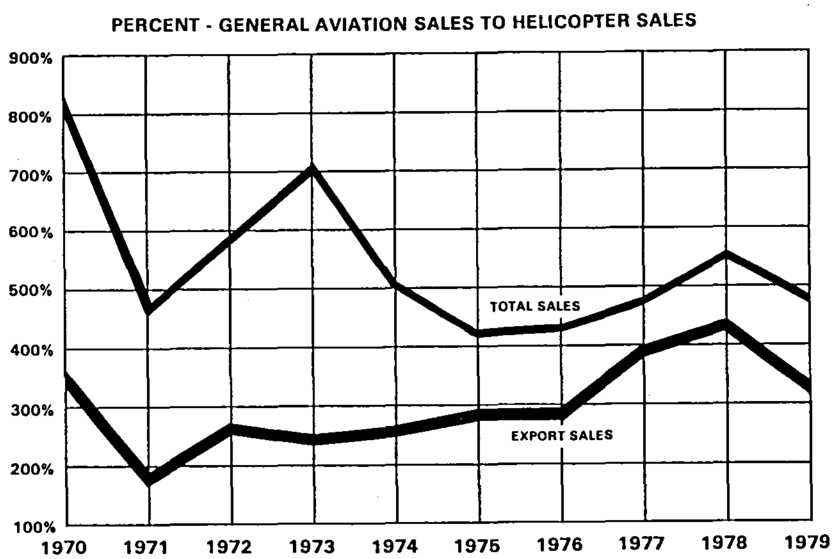


FIGURE 3

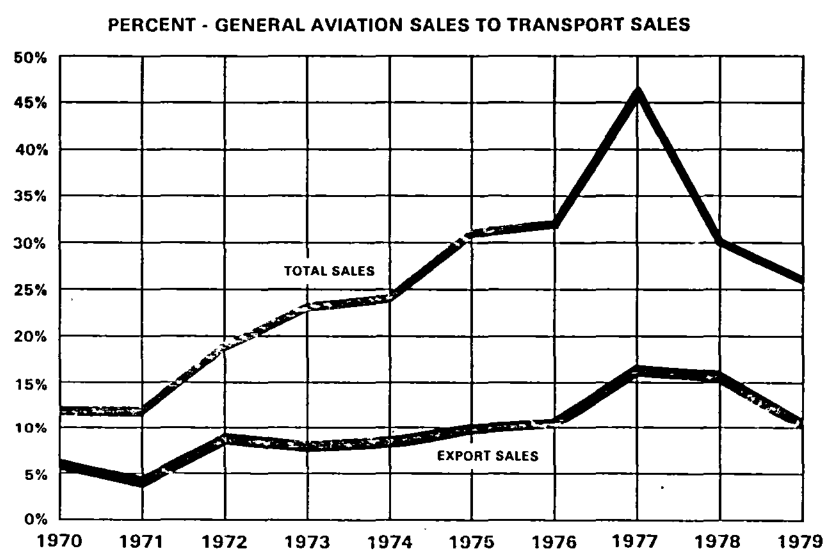
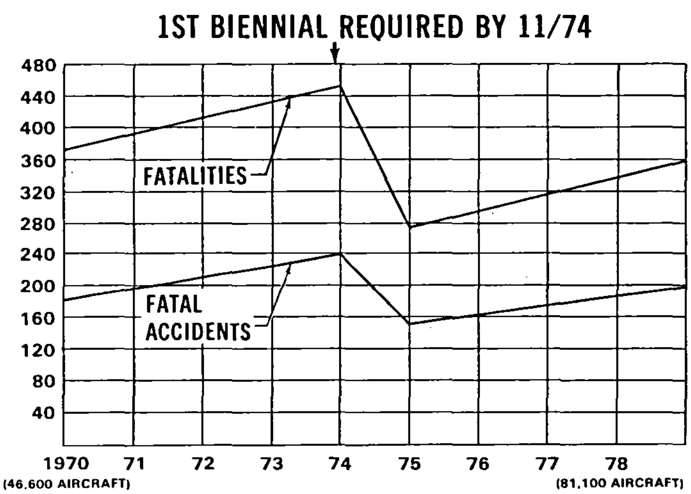


FIGURE 4

TABLE 1 Fatality Rates per Hundred Million Passenger Miles

Airliner	0.04
Overall general aviation	16.0
Passenger cars	1.4
Passenger cars on turnpikes	0.7
Skyhawks	7.0
421s	1.5
Citations	0.4



ANNUAL ACCIDENT RECORD - CESSNA DOMESTIC FLEET

FIGURE 5

TABLE 2 General Aviation Fuel Efficiency

	MPG (Statute)	Seat Miles Per Gallon
Skyhawk	17	68
Pressurized 210	12	72
421	7	49
Conquest	5.5	55
Citation II	3.5	30

COMPOSITE CHARACTERISTICS

MATERIAL	TENSILE STRENGTH 10^3 PSI	TENSILE MODULUS 10^6 PSI	COMPRESSIVE STRENGTH 10^3 PSI	COMPRESSIVE MODULUS 10^6 PSI	DENSITY #/CU. IN.
KEVLAR 49	200	11	40	10.5	.05
GRAPHITE	110	28	100	28.0	.06
ALUMINUM 2024 T3	60	10.5	36 (YIELD)	10.5	.10

(UNIDIRECTIONAL FIBERS IN EPOXY LOADED IN DIRECTION OF FIBERS)

TABLE 3

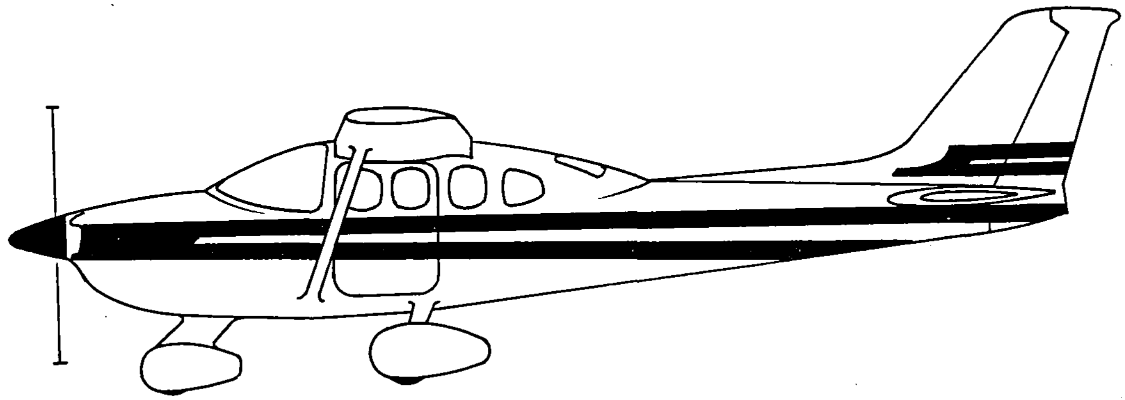


FIGURE 6 An Example of a Minimum 4-Place Aircraft of the Future

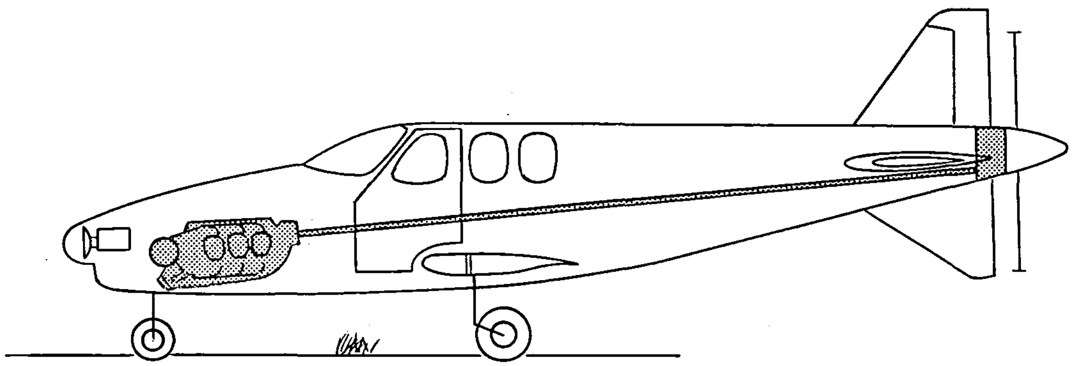


FIGURE 7 An Example of a Turbo-Charged Diesel-Powered 4-Place Aircraft

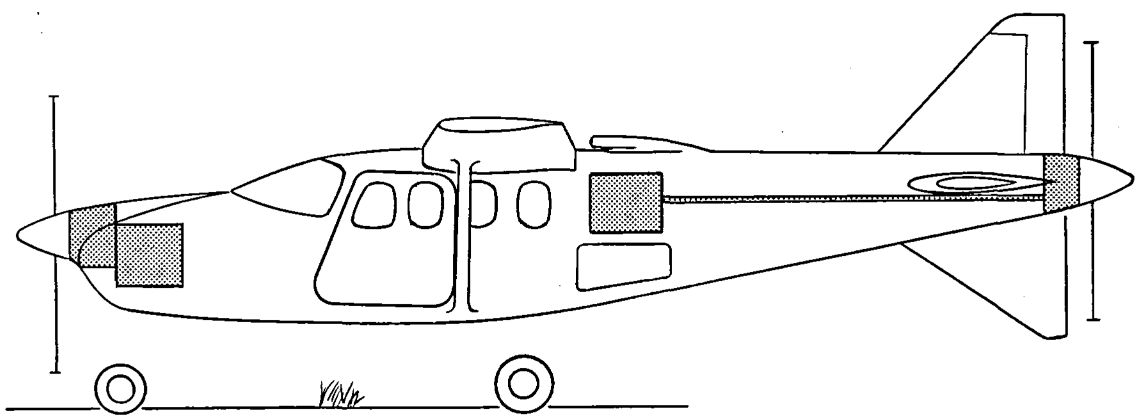


FIGURE 8 An Example of a Minimum-Cost Twin Engine Aircraft

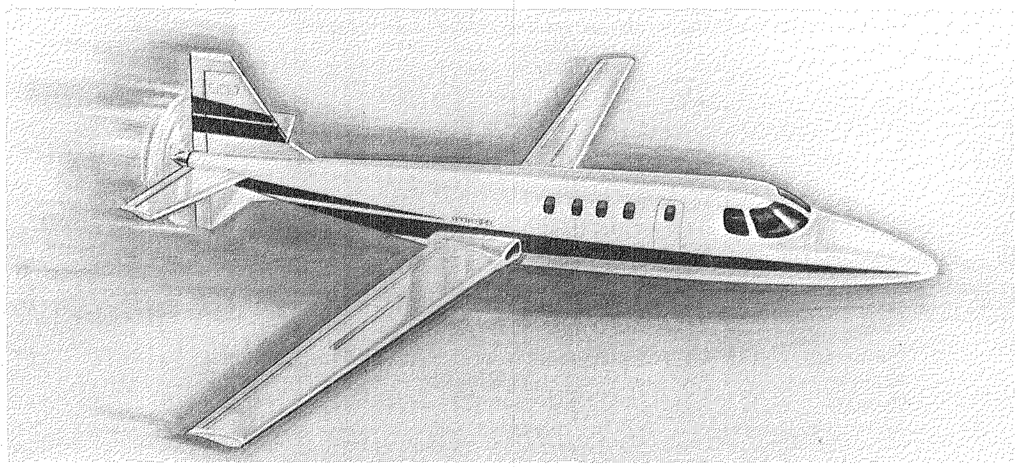


FIGURE 9 An Example of a Twin-Turbine Single-Propeller Aircraft

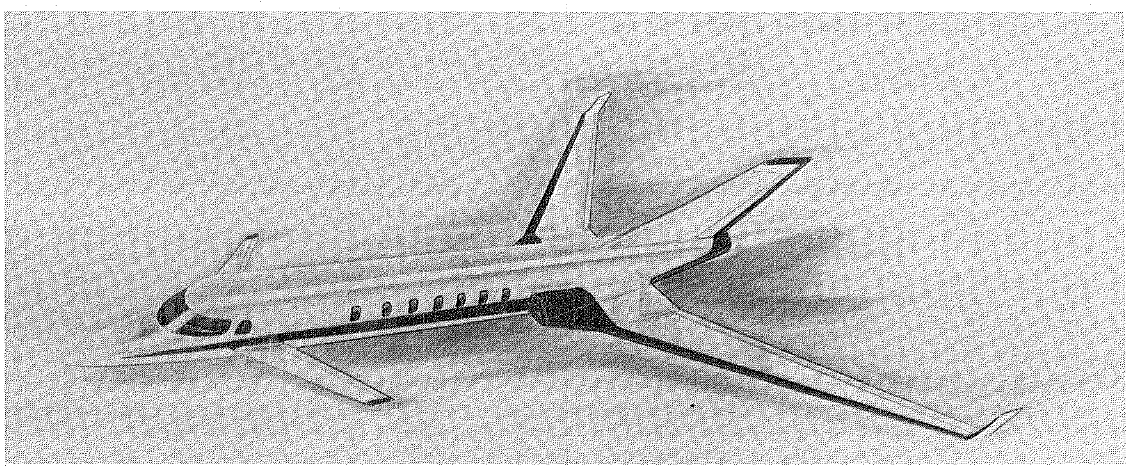


FIGURE 10 A Mach 0.95 Business Jet of the 1990s

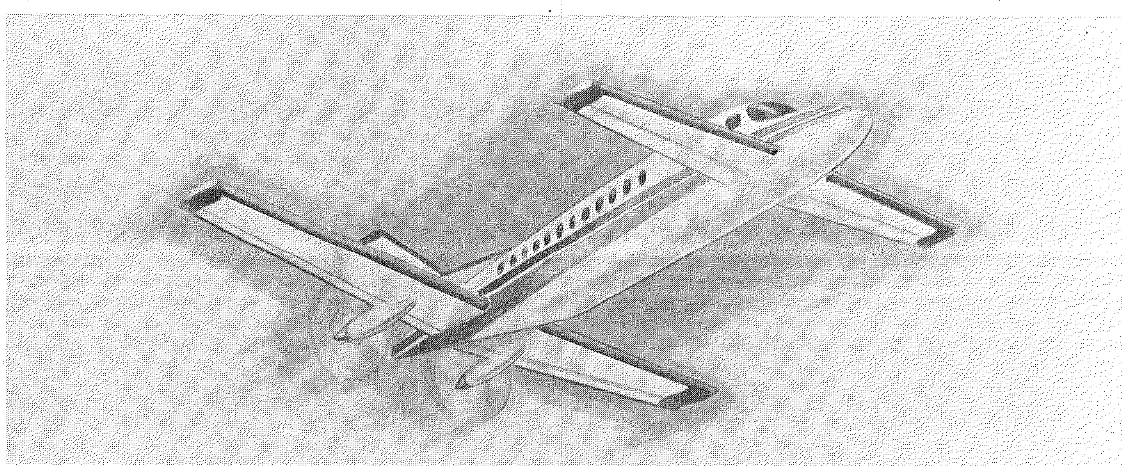


FIGURE 11 An Example of a Future 50-Passenger Short-Haul Commuter Aircraft

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THE HELICOPTER'S FUTURE: FRUITION OR FRUSTRATION?

Gerald J. Tobias
President
Sikorsky Aircraft Division
United Technologies Corporation

Thank you. It gives me a great deal of pleasure to participate today in this discussion on the role of NASA in aeronautics and to present to you one viewpoint from the helicopter industry.

My presentation this afternoon will consist of three parts. First, the helicopter market as I see it evolving in the next decade, including the key underlying trends and shifts that are occurring. Second, the role of the helicopter in our society. And, finally, the role that I believe NASA should play, not only in bringing this market to fruition, but also in ensuring that the U.S. helicopter industry receives its appropriate market share.

Over the last decade as illustrated in Table 1, the free world helicopter industry, which is primarily the U.S. and European manufacturers, produced 21,000 civil and military helicopters, with revenue at $15 billion. (All financial data are in 1980 dollars.)

In comparison, over the next decade we project that free world output of helicopters will rise to 29,000 units, with revenue estimated at $29 billion. These data provide an average annual growth rate in units of 3.2 percent, while, on a revenue basis, the rate is 7 percent. The inversion in these growth rates indicates another interesting statistic, which is that the average unit value will increase significantly.

Summarizing then from a business point of view, we believe that there is an attractive rate of financial growth, coupled with a clear shift toward larger vehicles, which is a fairly typical aerospace trend.

I will return to the question of vehicle size in a few moments, but first of all let me go over the question of the military/civil mix. Continuing with the statistics used earlier, Table 2 shows that the 21,000 helicopters produced between 1971 and 1980 were made up of

some 11,600 military and 9400 civil machines.

Our projections for the next decade indicate production of 8000 military units and 21,000 civil helicopters. The apparent decline in the military market is the result of the Vietnam War. It appears that the military market in units will change little over the next two decades, suggesting a replacement, rather than a growth, mode.

With respect to the civil sector, unit growth is a strong 8.5 percent, while the revenue growth is an even stronger 11 percent (Table 3). This strong growth of the civil sector in the helicopter market is of significance to NASA. What, perhaps, is even more important is the fact that the civil market is growing in a different technical direction--the military and civil markets are technologically diverging.

I believe this is a factor of great significance in the context of this workshop, since traditionally the technical community has become accustomed to strong relationships between civil and military designs. As an example, compare the Lockheed C-5 and the Boeing 747. Although their specific designs and utilizations differ, the requirements they meet and the environments in which they operate are sufficiently similar to permit a high degree of technical cross fertilization. While this is common in the fixed-wing industry, it is rapidly diminishing in the rotary-wing sector.

For example, our new helicopter, the Sikorsky SPIRIT, was conceived from the wheels up as a civil design (Figure 1).

The marketplace had reached a point where it was mature enough to make economically viable a privately funded venture. Of equal importance, that market could only be captured by an aircraft specifically designed for its needs. The potential market could no longer be won by a modified and repainted military aircraft.

The reasons behind this divergence can be seen by considering our new military design, the UH-60A Black Hawk (Figure 2). In simple terms, six factors dominated its design: threat survivability, rapid maneuverability, ability to operate at altitude and ambient temperature extremes, ease of air transportation, improved reliability and maintainability, and crashworthiness.

Unfortunately, as illustrated in Table 4, four out of six of these military attributes economically and/or operationally penalize the application of this aircraft in the civil market. Threat survivability features are irrelevant to operation of a civil helicopter and appear as added weight and cost in many vital components, such as rotor blades, drive systems, and controls. Rapid maneuverability requires excess installed power and design optimization for low-speed, rather than cruise, flight.

The capability for operation at virtually any altitude and temperature around the world again leads to excess installed power and a general lack of "balance" between the dynamic and structural components. The requirement for ease of air transportation physically limits the external dimensions of the Black Hawk in order to meet the internal dimensions of Air Force transport aircraft. The result is a passenger cabin envelope unsuited to civilian passenger standards.

It is only in the areas of reliability/maintainability and crash-

worthiness that the military attributes have a direct applicability to the civil design.

Now, let me return to the civil market projection I discussed earlier. You will recall from Table 3 we projected 21,000 units worth $13.6 billion for the next decade. In Figure 3, we divide this market into three gross weight categories--light, defined as aircraft below 6000 lbs.; intermediate/medium; and heavy, which are aircraft above 35,000 lbs. Just over three-quarters of the units are projected to be below 6000 lbs., and less than 1 percent are above 35,000 lbs. However, above 35,000 lbs. the civil market potential revenue is a miniscule 1.5 percent of total dollar volume and the lightweight class has shrunk from its 75 percent of units produced to only one-third of the total market revenue. I believe, therefore, that NASA should pursue areas involving the central core of the helicopter market--the intermediate/medium class.

Based on this premise, let us reexamine the civil/military technical divergence I mentioned earlier. Figure 4 shows some of the salient designs in this migration toward heavier gross weights in relation to the first flight of each aircraft. This trend indicates, I believe, that NASA should not only throw its technical authority generally into the intermediate/medium weight class but specifically into the 25,000- to 35,000-lbs. sector, which we anticipate will be emerging in the late 1980s.

It is through the development of vehicles such as this that the U.S. helicopter industry will aid in the continuation of its role in keeping our air transportation system the envy of the world and an efficient servant to the expansion of the United States economy.

Before proceeding, let me take a few moments to define the role of the civil helicopter in society as I perceive it. As you know, this aircraft has two very unique capabilities whose significance is frequently not fully appreciated, namely, the fact that it takes off and lands vertically and that it can sustain flight in a hover. This means that the helicopter serves both remote and congested areas with minimum investment in facilities and equipment. At the same time, in 1980 the helicopter is much more economical than circa 1960-1970 predecessors and is, therefore, becoming more competitive with fixed-wing aircraft in a wide variety of applications.

Helicopters are also more attractive to potential users because of substantive increases in creature comforts and convenience. For example, the new-generation helicopters can provide faster point-to-point transportation than current fixed-wing aircraft within a radius of 300 nautical miles or so.

The helicopter can now fill a number of roles in society as a complement to our existing transportation systems. It provides economic point-to-point transportation for key business and government people, not only in developed areas, but also in regions inaccessible by other means. In our population centers, the helicopter is ready to provide a flexible and economically viable solution to the problem of our congested fixed-wing airports. When flying point to point, helicopters can use "unused" airspace via helicopter air routes, thus contributing to the reduction in fixed-wing route congestion.

Additionally, as a service of inestimable value to society, the helicopter can provide emergency service to vast areas of the population at high speed and without the need for fixed-wing facilities. In the 40 years of the helicopter's existence, it is estimated that helicopters have been instrumental in saving over 100,000 civilian lives, not to mention the million plus military combat rescues and medical evacuations.

Now let me be more specific about the threat that the U.S. helicopter industry is facing, the help that is needed to defeat that threat, and the way in which NASA can provide the help. Figure 5 shows what is happening in the world helicopter market. While the U.S. helicopter industry has been holding its own, our European competitors, all heavily supported by their respective governments, have doubled their output.

My concern increases when I consider NASA's list of potential markets:

--Tactical fighter
--Long-range subsonic transports
--Supersonic transports
--General aviation
--Short-range/commuter transports
--Military V/STOL
--Improved military and civil rotorcraft

I fully appreciate the point that this is not a list of priorities, but the fact remains that of the seven items listed, six are fixed-wing oriented. Furthermore, while four of the six fixed-wing items are quite specific, the rotary-wing item is almost a meaningless generality.

An analysis of NASA spending does nothing to alleviate my worries. The data in Table 5 show that NASA expenditures in the last decade for fixed-wing transport research equates to one-fifteenth of the next decade's market revenue. The comparative figure for helicopters is 1 in 54.

NASA would have to spend $600 million on helicopters to catch up, or 2.5 times as much as in the last decade. And the payoff, in technical terms, will be rapid. I believe it is generally agreed that the helicopter has reached only about 50 percent of its technical potential, whereas the fixed-wing subsonic transport is very close to maturity. Helicopter research will provide rapid and visible advances, whereas fixed-wing research will require increasingly heavier funding for relatively marginal gains.

How can NASA help the U.S. helicopter industry? The greatest service I believe NASA can provide is to help us find out where we are now technologically, or to put it another way, to help us turn our remaining "black art" into a more formal science.

Those of us who have been around the industry for a little while will not forget the enormous contribution made by NASA in the 1930s, 1940s, and 1950s to the total understanding of the aerodynamics of the subsonic aircraft. I don't mean to belittle their contribution to the

understanding of the supersonic regime, but rather to give special recognition of the totality of their work in subsonic aerodynamics. The value of this work to the U.S. aerospace industry and the world was immeasurable, and it played a large part in placing the American commercial aircraft industry in the position of preeminence it holds today.

I urge the NASA of today to parallel the efforts of their NASA pioneers and help the helicopter industry get a total understanding of the very complex aerodynamic field in which our product must work. Obviously, we have made great strides but there is, I believe, much more to learn. A truly great effort on the part of NASA in fundamental helicopter research could contribute much to the American helicopter industry and most importantly to society at large. And the industry must participate so that the most effective use can be derived from all resources.

Beyond this, I have my own particular priority candidates for helicopter research. They come under the general heading of improved operational capability and are as follows:

--Development of helicopter instrument approaches
--Noise abatement
--Dedicated helicopter airways
--Cockpit integration and human factors
—Crashworthiness

In my view, success in these areas of research is essential if we are to enable the helicopter to play its appropriate role in relieving the traffic constriction in this country's air transport system. While the FAA also has a vital role to play in this arena, there is much that NASA can do to help. Important areas in which there is much to be done include the development of helicopter instrument approaches, the reduction of noise, the establishment of dedicated helicopter airways, cockpit integration and human factors, and crashworthiness. The payoff for this work would be almost immediate.

Airport congestion is now widespread, and saturation is becoming a serious problem in many major metropolitan areas. The airports that have already reached saturation are Washington National, Philadelphia International, Chicago's O'Hare, Los Angeles International, San Francisco International, New York's La Guardia, and New York's Kennedy International.

Considerable relief can be obtained by establishing independent helicopter airways and public-use heliports close to the centers of population. These can be made to work if the research is properly funded.

In summary, then, I see the role of NASA assistance to the helicopter industry to be, first, recognition of the separate needs and uses of the helicopter as an essential air transportation vehicle. I have expressed my views relating to the problems the helicopter industry faces in many professional forums. The most serious is being packaged in the same technical and operational box with our fixed-wing brothers. NASA must view the future by recogniz-

ing the significant distinction between fixed-wing and rotary-wing air vehicles and their respective contributions to society.

Second, NASA should provide assistance, along with the efforts of the FAA and industry, to develop a specific helicopter operating environment.

Third, NASA should provide a firm foundation of basic research by funding to a level that is appropriate to the potential contribution of the helicopter.

These actions will assist the U.S. industry in its effort to maintain a competitive posture with the rapidly expanding and nationally supported helicopter industries of Europe.

FREE WORLD HELICOPTER MARKET

	1971-1980	1981-1990	Average Annual Growth Rate
Units	21,000	29,000	3.2%
Value of new Helicopter Production (1980 Dollars)	$15 Billion	$29 Billion	7.0%
Average Unit Value	$0.7 Million	$1.0 Million	

TABLE 1

FREE WORLD HELICOPTER MARKET DISTRIBUTION
OF CIVIL & MILITARY MARKETS

	1971-1980	1981-1990
Military	11,600	8,000
Civil	9,400	21,000
Total Units	21,000	29,000

TABLE 2

CIVIL MARKET GROWTH

	1971-1980	1981-1990	Average Annual Growth Rate
Units	9,400	21,000	8.5%
Value	$4.7 Billion	$13.6 Billion	11.0%

TABLE 3

FIGURE 1 Sikorsky SPIRIT™

FIGURE 2 Sikorsky UH-60A Black Hawk

BLACK HAWK

Military Attributes	Civil Market Penalty
o Threat Survivability	o Weight Irrelevant Features
o Rapid Maneuverability	o Excessive Installed Power Optimized for Low Speed
o World Wide Capability	o Excessive Installed Power Dynamics-Heavy Design
o Ease of Air Transportation	o Design Constrained Cabin Size Unacceptable
o R & M	o None
o Crashworthiness	o None

TABLE 4

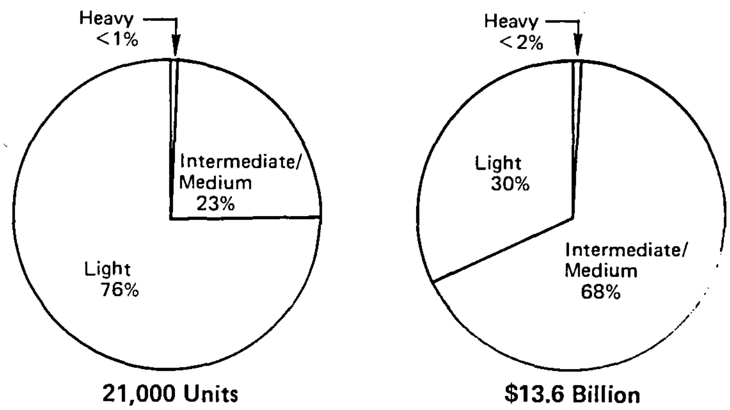

FIGURE 3 CIVIL MARKET FORECAST BY WEIGHT CATEGORY 1981-1990

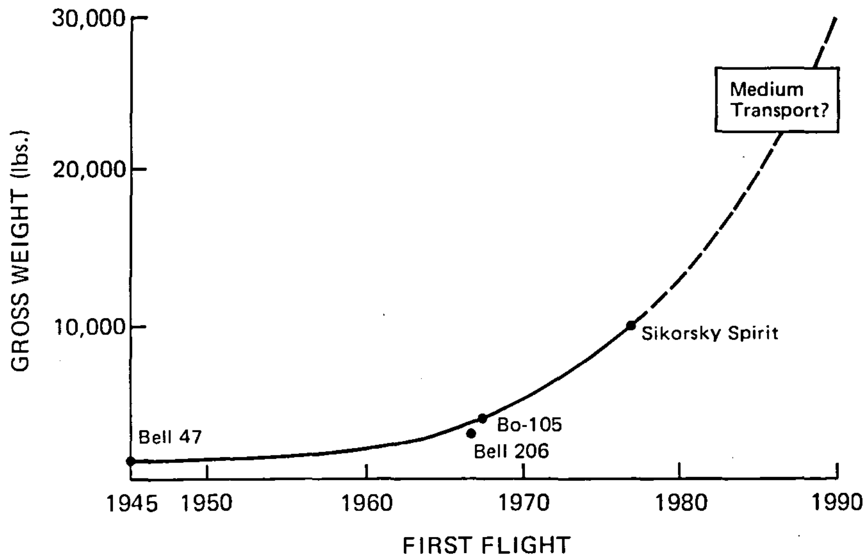

FIGURE 4 EVOLUTION OF CIVIL DESIGNS

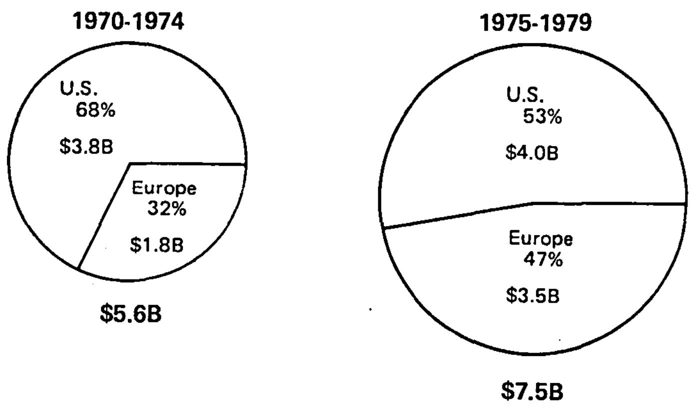

FIGURE 5 GROWTH OF EUROPEAN COMPETITION (1980 Dollars)

NASA RESEARCH SPENDING VS. MARKETS

<u>Fixed Wing Transport</u>	
Research (1971-1980) = $7.0 Billion	Ratio 1:15
Market (1981-1990) = $103.0 Billion	
<u>Rotary Wing</u>	
Research (1971-1980) = $0.25 Billion	Ratio 1:54
Market (1981-1990) = $13.6 Billion	

TABLE 5

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HOW NASA CAN ASSIST THE FAA

Charles R. Foster
Director, Northwest Region
Federal Aviation Administration

Neal Blake and I will both address the issue of assistance from NASA as far as the FAA is concerned. I thought it might be wise for me to discuss the background for this presentation, both mine and his, starting with the mission of the FAA, what we are about, and where and how we are going.

As you know, one of the major areas where NASA can participate with the FAA deals with our charter for the development and growth of civil aviation, as well as for providing and maintaining the highest level of safety in air transportation. We can break that responsibility into a couple of different areas, one dealing with the management of the navigable air space, or the air traffic side--and Neal will be discussing more of that than I--and the other side of the issue having to do with the aircraft and the aircraft operations. I would like to spend my time dealing primarily with some of the issues relative to those two elements.

First, in the aircraft, we start with the actual design of the vehicle, how it is manufactured, and how it is maintained. We group these three together, and we identify all of them with the airworthiness of the vehicle. So, we have a major role in the airworthiness of the vehicle, both initially as well as on a continuing basis. In the operational area we are dealing with the flying of the vehicle. That includes the procedures that we use, the training of the crew members, the types of people we have aboard the airplane, the numbers we have, the human factors, how they interrelate, the individual, and the machine itself. This we lump into our operational side of the house. So, airworthiness and operations are two major areas where NASA has been able to contribute to the FAA's overall mission in the past as well as today.

It is interesting to note that NACA, which came into being in 1915, had a budget of $5000. In NASA, today, the budget is about

$5 billion. That is quite a jump from 5000 to 5 billion in this time span. I am sure that in 1915 if anyone had projected the most you would ever see in any budget for any government agency the word "billions" would not even have been used. A person's judgment would have been questioned if he had predicted as much as a million dollars for an agency engaged in aeronautical research.

One of the issues is how and where the aeronautical part of this budget should be spent. I have heard several people here discuss the issue of fundamental, or pure, research. There are some who question whether NASA should go beyond that into the development of technology, even into operational feasibility; in other words, what part of the spectrum of aeronautical research should be done by NASA?

In addressing this issue for the 1980s, we should not focus strictly on NASA and NASA alone as if there, and there alone, is where the research is going to be done. In my dealings with the Office of Management and Budget many times in the past, when we would ask for funds for research, the general question we would get would be whether this is not something that NASA should be doing. So, we would have to justify why it was something that the FAA or some other part of the Department of Transportation should be doing, even though the generic term may apply across the board to NASA, the Department of Defense, and others.

So, if we are not careful we can wind up having the research identified with one organization such that there may be, because of administrative procedures and processes, an inability to get the funds or resources equitably distributed according to the priorities that we see as far as the value of the research products.

I will address, first of all, transport aircraft. You have heard some excellent speeches dealing with our role in the transport aircraft business, where we stand today, the challenges we have, the leadership we have had in the past, what we need to do, and where we should go to maintain the leadership for the future. I think that the area of rotorcraft is one that has not received the attention it should have in the past. In the FAA I think that we have all too often dealt with the field of aircraft, and 99 percent of the time we think of airplanes. We have put out regulations that, once they were in the field, people have questioned whether we really meant for them to apply to helicopters. The answer was, goodness no, we were not thinking about helicopters, we were thinking about airplanes. We have not addressed the requirements for rotorcraft with the same priority and resources that have been given to airplanes. For example, in the area of icing, I think it is unfortunate or worse than unfortunate that we have foreign governments that have certification criteria for icing of rotorcraft and we do not have them in the United States. This is a case, I think, where we have not done the kind of research that we should have done in the past or we would have had the information necessary for us to develop these kinds of certificaton criteria.

Commuter aircraft. As you may know, the FAA certificate aircraft according to type. We have the categories broken down in which we have specific Federal Aviation Regulations. They are divided into

different parts for different categories of aircraft. For example, Parts 27 and 29 deal with rotorcraft. Part 23 deals with utility, acrobatic, and light aircraft. Part 25 deals with transport category aircraft. We have been working for about 4 or 5 years to determine whether or not we need to put out a new part, a Part 24, for aircraft that are between the smaller general aviation category and the heavy transport category. Why have we been spending this time on Part 24? Because we feel there is a requirement to develop an aircraft that is really designed to satisfy the commuter market. Unfortunately, most of the aircraft that are designed for the commuter market and sold in the United States are not manufactured here nor are they designed here. The aircraft that fit into this market are those that have been developed for business executive aviation or general aviation and have been expanded or modified to fill the gap. Here is an area where, I think, we could get some input from NASA into the basic fundamentals necessary to put together a truly effective commuter aircraft.

The general aviation side of the picture. I think Mal Harned made some good points dealing with that. We are killing too many people stalling and spinning aircraft. Aircraft do not have to have those kinds of characteristics. We can build airplanes that will not spin, that will not stall, and that will still perform the mission for which most people buy a private airplane.

Lastly, I have to touch on my previous assignment delving into government dealings with the environment. Since I spent many years in that area, I would like to touch on a couple of things that I think NASA can assist us with in our dealing with environmental issues, particularly as far as noise is concerned.

Across the spectrum of types of aircraft, one of the areas that has been discussed here and will continue to be discussed at some length has to do with composite materials. We are developing information about composite materials and are employing composite materials in some of our aircraft today. It was interesting to hear Gerry Tobias' comment regarding the percentage of the Spirit helicopter that actually is composite, even the primary structures. We need to know more about how we are going to certificate composite materials. We need to know more about the damage tolerability of composite materials. What are the effects on the environment in which these materials will operate? What happens after 5 years, 10 years, or 15 years? What kind of nondestructive testing can we have? How can we be sure, both in the initial development testing and in the proving of the product, that it is safe and meets the criteria as well as the continued airworthiness of vehicles using composite materials? I think that we have not properly addressed all of these areas, and I think many times we spend too much effort, as far as the FAA is concerned, on identifying unique characteristics on too small a scale.

Obviously, we would like to see the work in aerodynamics and control of aircraft continued. One of the concerns we have today has to do with transsonic flutter analysis, particularly shock-induced flutter that can be developed on some of our supercritical wing airfoils.

Active controls. We are making some progress in active controls.

We feel that further research needs to be done in this area.

One of the largest areas is the human factors work. We are moving in the area where we are having more and more things done in a cockpit, either through mechanical means and/or electronics. As the airplane cockpit becomes more complex we are able to handle more things automatically. The big question is how to resolve the work load problem to make sure that we do not put so much in the cockpit, so many different kinds of instruments, radios, what have you, that the crew work load is not increased.

It is interesting to note that we have gone from crews with as many as 4 and 5 members, 10 to 16 years ago, down to 2 and 3 today. The important thing is being able to quantify how we can reduce this work load by the development and interface of various electronic and mechanical pieces of equipment.

Another area that we need to improve is the propulsion system, particularly for transport aircraft. We have had quite a few discussions dealing with various types of modification and improvement of existing turbo machiners, development of new types, new and different kinds of fuels, and new means of propulsion.

I would like to throw out one subject that has not been covered--that is the reliability of our new propulsion systems. In the early days of the DC-4s, DC-6s, Constellations, and Stratocrusiers, we had airplanes that had four reciprocating engines. In those days, the engine failure rate was running around 400 and 500 flight hours per engine shutdown. Along comes the turbojet and we hardly ever have an engine failure.

Actually, most of the turbojets are removed because of time limits. In the days of predominantly four-engine airplanes, we had aircraft land with one engine shut down--sometimes two engines shut down. I think the 747 will be the last large four-engine aircraft built. We are moving more and more toward two- and three-engine aircraft. Our newest, latest aircraft are coming out with two large high-bypass-ratio engines.

So, as we delve into the means of improving the specifics, reducing the weight and many other factors that deal with the propulsion system, we must also make sure that we provide adequate attention and time to the reliability of these machines. Two-engine failure of a twin-engine airplane is entirely different from two-engine failure on a three- or four-engine airplane.

Lastly, I would like to comment on the environmental concern. We have moved from the arena in noise where we were, I guess 15 years ago or so, really trying to find the fundamentals of how noise was generated; what were the mechanisms involved particularly in the jet exhaust? We were developing means of suppressing the noise or modifying the design so that the noise was not generated. And we have made tremendous progress. Unfortunately, we still have a lot of aircraft with old engines that will be flying over the next 5 or 10 years that will not incorporate a lot of the technology that we have developed and applied to the newly produced airplanes.

As we have moved from concentrating on the source of the noise in our propulsion systems, we are now in the area of major legal issues,

and people are going to court because of the noise exposure they are receiving. In California, the airports are now paying compensation for noise nuisance, and indications are that the recipients can go back and back if the nuisance is not removed. As this spreads across the country the impact could be devastating on our whole transportation system.

One of the problems that I see in this is the method for determining what the noise exposure is. We have some very sophisticated noise map or noise contour modeling procedures both within the Department, the Air Force, NASA, and other places. NASA has a large facility at Langley that is working on this particular problem. The computer program will do an excellent job of taking the input and drawing out all these contours. The courts take the contours and determine what the noise may be or should be. But, if you go out and start measuring around these contours to validate the contours through measurements, you find one of the fundamental problems we have and that is our ability to truly predict what the sound pressure level is going to do, the content of the sound, as it propagates over long distances. This is a long time, I think, for an expensive type of research that needs to be completed. We still have limited results from research dealing wth this long-range propagation of sound. Over the last 15 years, I think we have made tremendous progress in aircraft noise reduction.

So, dealing with the aircraft and its operations, I have indicated the types of aircraft (transport, helicopters, commuter, and general aviation) for which I feel we need input from NASA to assist us in modifying our regulations and developing new criteria. Composite materials, aerodynamics, human factors, propulsion, and the environment are the five areas that I felt would be worthwhile mentioning and highlighting at this time. I would like to say, in conclusion, that these things are not all that we are interested in.

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HOW NASA CAN ASSIST THE FAA

Neal Blake
Deputy Associate Administrator for
Engineering and Development
Federal Aviation Administration

Although predicting the future is an inexact science at best, I think certain trends have been identified that have helped us to assemble a scenario for the shape of the air traffic control system of the future. This scenario, in turn, has been used to identify development activities that we need to complete to provide a higher capacity, more automated, more fuel-efficient system for 1990 and beyond.

Today, I will give you a very brief overview of some of the impacts of traffic growth, our development program goals, our future air traffic control system scenario, and present and planned activities in the development area to support that scenario and I will try to identify some of the key areas for NASA support in this program.

In his paper, Bill Wilkins indicated that we still expect continued significant growth in the number of aircraft requesting FAA separation services over the next decade. The forecast of growth in aircraft operations under instrument flight rules handled by our air traffic control centers is expected to be approximately 60 percent by 1990. The greatest percentage of growth is expected in general aviation, air taxi, and commuter operations. Air carrier growth, as noted yesterday, will be slower, and military operations are expected to stay about the same.

The forecast growth in air traffic handled by the individual air traffic control centers will range from about 35 to 67 percent during this time period. Operations at tower-equipped airports are expected to increase about 44 percent during this same time period--again, the big growth will be in general aviation, air taxi, and commuter operations.

This forecast growth and achievement of significant gains in each of the five major FAA goal areas provide most of the basis for our

engineering and development program.

The first goal is safety. Our highest priority has always been given to improving system safety and reducing flight risk. This goal area encompasses the development activities needed to prevent aircraft collisions with terrain and other aircraft, to reduce fatalities from inflight and postcrash fires, to detect and reduce the consequences of human error, and to detect and avoid severe weather phenomena.

The second goal is system performance. Improving system performance by increasing capacity, reducing delays, and improving weather and pilot briefing services has been a goal of many of the recent development programs that are just now providing field implementable systems. This area includes programs to increase airport capacity, provide more direct aircraft routings with fuel-efficient profiles, and provide improved flow management particularly during adverse weather conditions.

The third goal, increasing system productivity by providing improved service while reducing the cost of providing these sevices, is becoming an ever increasingly more important goal area. The activity to improve both the weather and pilot briefing services while simultaneously reducing the cost of providing those services is already well under way.

Additional development programs are aimed at reducing the operation, maintenance, and certification costs of the air traffic control system.

As Bill Wilkins mentioned, fuel conservation has become an increasingly important goal area and a number of procedural and facility improvements designed to conserve fuel are already entering the system. Additional automation activities are under way, which we expect will further reduce the excess fuel burned due to air traffic control and weather delays.

The last goal, protection of the environment, is an area related to the reduction of aircraft noise and control of engine emission both through procedural changes to the air traffic control system and improvements to aircraft and aircraft engines. This goal is heavily supported by a number of FAA and NASA programs.

Now, in looking ahead to the air traffic control system of the 1990s and beyond, we see continued growth in the demand for services; a need to provide the higher level of automated coordination required to permit controllers to issue direct-route, fuel-efficient, conflict-free clearances in more of our air space; a continuing need to achieve the most efficient use of the nation's existing airports; and a pressing need to control the growth in the cost of providing the service.

So, within this general context we see the future trends for the various elements of our system as follows. In the airport area we do not believe that there will be a significant number of new airports or even new runways at existing airports, particularly in the major terminal areas. Our current program to equip satellite airports with approach and landing aids and control services may provide some added commercial capacity at these airports if such improvements in fact cause a migration of general aviation activities to the satellite

facilities.

Hence, our programs in the airport area will continue to focus on increasing the life of runways, reducing pavement test time, providing improved airport surveillance systems, and, later in time, automated surface traffic control systems and improved hazardous weather and wind shear detection forecasting and avoidance systems. These new systems, operating in conjunction with a more automated air traffic control system, will permit us to make the most efficient use of our airport resources, particularly in the high-density traffic areas.

Airport capacity. Congressman Harkin brought that one up yesterday. The airport capacity program includes studies of each of the nation's high-density airports, that are conducted to determine the improvements that are feasible at each airport and to assess the benefit of implementation of each of the possible improvements. This program covers a wide spectrum of improvements, including additional runways, short runways, runway exits, taxiways, procedural changes, and systems that will permit reduced longitudinal spacing between aircraft on the final approach. The latter includes vortex wake detection, prediction, and avoidance and vortex alleviation on aircraft, automated terminal metering, and spacing systems.

Improved automation and navigation systems on the aircraft will interface directly with the ground metering and spacing computer to offer still greater precision in the delivery of aircraft to the runway.

Navigation. The navigation system today is based primarily on Vortac for short-range navigation and Omega and Inertial Navigation System (INS) for long-range navigation. Other aids are used, but these are the primary ones. INS, with external updating from other aids, is used in the continental U.S. as well as in oceanic areas and currently permits Air Traffic Control (ATC) to issue direct clearances to equipped aircraft, particularly in the area west of the Mississippi River. With the implementation of automated assistance to the controller in coordinating direct-route clearance between controllers, we expect that most high-altitude flights over the U.S. could be conducted via direct routing with the proper equipment in the aircraft.

The demand for ATC service for low-altitude IFR helicopter operations is increasing rapidly, and development and test efforts have been increased with a view toward early certification of Loran-C as a supplementary aid to Vortac and Omega to meet these special user requirements in areas where the Loran-C coverage is adequate.

Now, looking to the somewhat longer term, the Global Positioning System (GPS) may provide the basis for navigational services in some air space. While many questions concerning this system are yet to be answered, such as its accuracy for civil use, the number of satellites to be used, the redundancy needed for satellite failure backup, and its vulnerability to hostile action, we believe that GPS may offer, in the 1990 time period, a global navigation service supporting the needs of aviation, particularly in the oceanic and low-density traffic areas throughout the world. Although use in domestic areas will depend to a large extent on decisions yet to be taken, a development program is under way to explore the use of this system in all air space.

We believe that airborne navigation systems will contain area navigation computers that can accept navigation signals from a variety of sources, including INS, Omega, Loran, Vortac, GPS, and the Microwave Landing System (MLS) and automatically adjust to the characteristics of the selected system and provide outputs to a variety of systems and displays, including graphic displays. These new systems can provide the pilot with guidance in reaching checkpoints at times and altitudes either generated internally by aircraft fuel performance computers or by the ground air traffic control system.

The FAA is nearing the end of the development cycle on a number of the systems needed to provide the base on which the more efficient automated systems of the future will be built. These systems include the discreet address beacon system, the MLS, automated flight service stations, and aircraft separation assurance systems. The last includes conflict alert and conflict resolution to warn the controller of impending loss of separation, the automatic traffic advisory and resolution service, and the beacon collision avoidance system to warn the pilot of impending disaster. These systems are all scheduled for implementation during the 1980s.

Major development activities have already been started to produce the improvements needed to support the system of the 1990s. Some of the major efforts include:

- o Replacement of the present air traffic control computers, starting with those installed in our air route traffic control centers, with computers providing the greatly increased capacity and reliability needed for the future. This is planned for the late 1980s.

- o Upgrading of the communication system to provide for more efficient, more reliable, and lower cost services.

- o Development and implementation of a real-time severe weather detection, processing and display system to provide accurate identification of the hazardous areas of storms to pilots and controllers.

- o Continued high emphasis on improving aircraft airworthiness and post-crash fire safety.

- o Airport and airspace capacity and delay programs will be expanded to provide a more efficient traffic flow management system.

- o Increased emphasis is being placed on the human factors programs to reduce the number of accidents attributable to human error.

FAA engineering and development has looked to NASA for some of the basic research and technology development needed in areas where the

current technology base is not adequate to support our program goals, as well as for some direct program support in critical program areas. The output from the NASA program provides the data base needed to formulate advisory circulars, regulations, and new air traffic control system improvements. I believe that the relationship between NASA and the FAA has been an extremely productive one, and steps are being taken continually to further strengthen it.

The coordinated programs already cover a number of important areas, a few of which include aircraft safety, covering fire safety technology, the effects of using antimisting kerosene on jet engine performance and life, general aviation and transport aircraft crashworthiness, vortex alleviation, and landing dynamics.

The second area, aircraft avionics systems covers advanced integrated flight controls, the terminal configured vehicle programs, the MLS, heads-up displays, cockpit display of traffic information, automated terminal service, automated pilot advisory service, lightning effects on avionics, the low-cost GPS receiver, and general aviation technology programs.

The materials and structures area, which was covered by Mr. Foster, includes the advanced composite materials and structures and lightning effects on composite materials.

There are a lot of other areas, such as search and rescue equipment, helicopter air traffic control operations, pilot training, and measurement techniques.

Now, from this quick overview of the areas of the coordinated programs, you can see that much of the basic research and technology needed to support our future air traffic control system development are already well under way. We believe, however, that augmentation of several of these areas is needed because of the high payoff in terms of system improvement that would result from successful technology development. I have listed four.

Certainly, vortex alleviation is near the top of the list. The introduction of the wide-bodied aircraft into the fleet highlighted the problem of weight vortices and resulted in increased aircraft separation minima. This, in turn, reduced the capacity of our major terminal facilities by 15 to 20 percent. Now, some capacity gains can be and have been achieved from procedural changes and implementation of our future automated systems, both air and ground. The technical problems associated with vortex alleviation, I realize, are very difficult but some encouraging results have come out of past tests. The payoff for successs is very high in terms of airport capacity. We would urge a continuing high level of effort in this area to identify techniques that would alleviate the strength of vortices.

Human factors. In the human factors area, basic research is needed on the causes of human error and the effects of pilot boredom on performance, particularly in emergency conditions. Closely related to these factors is the need to develop improved warning systems that can prioritize and present the key actions a pilot must take when an emergency exists and every second is precious.

The fire safety area. Much progress has been made in the development of an antimisting kerosene additive, and some encouraging

large-scale test results have been achieved. Progress in the development of improved cabin materials has been somewhat less dramatic, and sustained high emphasis on new materials development continues to be needed.

The use of simulators for pilot, aircraft, and rotorcraft certification is another area. While much progress has been made in the use of simulators for pilot certification and training, continued activity is needed to determine the extent to which simulators can be used in the certification process for aircraft and rotorcraft. NASA assistance is needed in the development of methods of verification and validation of computer models used by the manufacturers in the certification process.

HOW NASA CAN ASSIST THE DEPARTMENT OF DEFENSE IN AERONAUTICS

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During the next few minutes I will try to give you a brief overview of how NASA can and does assist the Department of Defense (DOD) in aeronautics and particularly in aeronautics technology. I am sure that I do not need to describe to this group why aeronautics technology is of critical importance to the DOD. You may be interested, however, in a quantitative measure--dollars--of just how important it is. Table 1 shows data from our FY 1981 budget. More than $2 billion are allocated to Research, Development, Test, and Evaluation (RDT&E) on aircraft and related equipment. Nearly $300 million will go to system-oriented aeronautics technology, including aircraft engine technology as well as airframe technology.

The operational uses for the DOD aircraft now in service, and for the technology of interest to this group, are listed in Table 2. Some of the new technology required to provide these capabilities is closely related to that needed by commercial aircraft--fuel economy, for instance--even though the reasons for needing it may not be entirely the same. We need increased range for logistic aircraft, with reduced fuel cost a secondary benefit. Commercial aircraft need lower operating costs, with greater range a secondary benefit. But the technology in this case is the same. In quite a few other areas, of course, DOD needs are not parallel to any commercial demand. In many of those cases, too, NASA provides direct support to us.

As indicated in Table 3, DOD does not do all of its own aeronautical technology work, or even the principal fraction of it. We have always relied upon a strong, complementary technology base in NASA, industry, and academia. DOD cannot and should not support a complete technology base activity covering all aspects of the application of air power to the DOD mission.

Table 4 itemizes the principal aspects of our relationship with NASA. Both agencies have statutory authority to conduct aeronautical research under the Space Act of 1958. NASA has extensive experimental facilities and concentrates on the scientific disciplines that form the aeronautics technology base for all development whether civil or military. DOD, on the other hand, is more systems oriented; however, the Department conducts sufficient basic research to maintain competency, does exploratory development pertinent to its operational needs, and carries out technology demonstration as needed to reduce system risk.

NASA technical personnel currently assist DOD in all phases of aircraft development, including preliminary design in which NASA helps with performance prediction assessment. For example, manufacturers may be required to submit wind tunnel models to NASA for independent evaluation, solving problems occurring in the flight test phase of development. NASA expertise is of immeasurable value when significant operational problems occur with military aircraft in service. For example, we rely on NASA's help in deriving aerodynamic modifications needed when external carriage of ordnance is required on operational aircraft that was not anticipated in the original aircraft design (Figure 1) or when changes in flight regime are required by changed operational needs--such as low-altitude penetrator flight patterns for the B-52.

DOD and its contractors make extensive use of NASA experimental facilities. NASA has over 30 major aeronautical research facilities, some of which are unique in the Western world. Noteworthy examples are the 40- x 80-foot wind tunnel at the Ames Research Center in California and the transonic aerodynamics tunnel at the Research Center in Langley, Virginia. The DOD accounted for over 15,000 hours of NASA wind tunnel time during FY 1979. The cost of military aircraft development would increase significantly if NASA facilities were not available, and some critical work could not be done at all.

A very important joint DOD-NASA activity, now well along in implementation, is the cooperative development of major new aeronautical research facilities. Examples of these are the National Transonic Facility located at NASA's Langley Center, the Aeropropulsion Test Facility located at the USAF Arnold Engineering Development Center at Tullahoma, Tennessee, and the 80- x 120-foot tunnel at the NASA Ames Center in California.

NASA has unique flight simulation capabilities that have been and are of great help to the DOD. The Differential Maneuvering Simulator at Langley is used for evaluation and development of new fighter/interceptor concepts. Similarly, the Flight Simulator for Advanced Aircraft at Ames in invaluable in the development of short takeoff and landing (STOL) and large aircraft. The new Vertical Motion Simulator at Ames will be immensely important in development of V/STOL aircraft and advanced helicopter concepts.

NASA/DOD joint programs in aeronautical technologies are in full and productive flower. Currently, there are more than 46 formal and informal joint program agreements to develop and demonstrate aeronautical technologies of mutual interest. Recent examples of such

programs include the KC-135 winglets development, which reduces aircraft draft by 5 percent and increases range by reducing range consumption proportionately; shipboard STOL demonstration conducted by the Navy, utilizing the NASA-developed STOL demonstrator, the Quiet Short Haul Research Aircraft; and joint NASA/Army development of XV-15 Tilt Rotor Research Aircraft.

NASA is the sole developer of technology for utility and transport type aircraft. DOD relies on NASA for this technology in the development of cargo transport and, to some extent, bomber aircraft. It should be noted that recent actions by the Office of Management and Budget curtailing NASA activity in the development of primary composite aircraft structures for large aircraft will have an adverse impact on the development of the next aircraft--the CX. There are insufficient resources in the military aircraft DOD program to take up the slack in this important effort.

Table 5 lists several ways in which it is important that NASA assist DOD in the future. In particular, we would urge the following:

1. NASA should maintain high interest in advanced aeronautics technology and continue to be the leading edge of technology oriented toward military aircraft development. The capability to explore and develop advanced technology when no formal "requirement" exists is vital to maintaining superior military aircraft. Examples of the kind of work we have in mind are the HIMAT Research Vehicle to demonstrate highly maneuverable fighter aircraft configurations and the F-16XL, the joint NASA/General Dynamics effort to develop a wing with 50 percent increase in supersonic lift/drag ratio, increasing it from 4 to 6 at mach 1.6, while maintaining good transonic maneuver performance.

2. NASA should carry technology development through the validation phase. This is necessary to ensure adequate technology readiness for new developments and to provide feedback to the technologist; technology cannot be developed open-loop.

3. NASA should expand flight simulation activities and capabilities, particularly those related to defense needs.

- o Increased sophistication of aircraft and weaponry is causing paper analysis techniques to be of reduced value. The need for good simulation testing has increased to the point of indispensability.

- o NASA currently leads the United States and Western world in simulation capability and should maintain that lead. NASA simulation facilities and erpertise should be considered a national asset and supported accordingly.

4. The present DOD-NASA relationships in aeronautics should be continued as a basic ingredient for a successful military capability.

In summary, as noted in Table 6, it is concluded that NASA

aeronautics technology developments are vital to DOD. This is the case in development and use of RDT&E facilities as well as in technical expertise in all aspects of aeronautics. There are several reasons for this:

- o Advanced technology work must begin before requirements are clearly identified. To wait keeps us behind the "power curve" in terms of time and money and may ultimately affect the security of our country.

- o Flight validation of new technology gives us the information we need before we risk taking it. Furthermore, it provides the feedback needed by the technologist to refine and improve his technology.

- o Joint programs provide the stimulus needed to "force" technology to move forward. Specifically, they enable NASA technical personnel to become aware of DOD needs and at the same time provide necessary technical expertise to DOD.

- o Civil aircraft technology is and will remain very important to DOD, especially in the logistics aircraft field. We are totally dependent upon NASA for this technology.

- o Finally, we would encourage support for NASA to expand its flight simulator capability. It is already excellent and indispensable to our needs, and as aeronautical technology continues to develop it will become even more critical to us.

AERONAUTICAL TECHNOLOGY CRITICAL TO DOD

IN FY 1981:

- $2232. MILLIONS WILL BE SPENT ON RDT&E FOR AIRCRAFT AND RELATED EQUIPMENT

  THIS IS 13.5% OF THE RDT&E BUDGET FOR DOD

- $283. MILLIONS WILL BE SPENT ON AERONAUTICS TECHNOLOGY

  THIS IS 12.6% OF THE RDT&E BUDGET FOR AIRCRAFT

  IT IS 1.7% OF THE TOTAL RDT&E BUDGET

TABLE 1

MILITARY AIRCRAFT USED IN WIDE RANGE OF MISSIONS

- GAIN AIR SUPERIORITY IN THE BATTLE AREA
- INTERDICT MOVEMENTS OF ENEMY TROOPS AND MATERIEL
- AUGMENT AND DIRECT GROUND AND SEA BASED FIRE POWER
- FORWARD AREA SUPPLY
- QUICK REACTION, LONG RANGE TROOP REINFORCEMENT AND SUPPLY
- MAINTAIN SEA LANES OF COMMUNICATION AND SUPPLY
- STRATEGIC DETERRENCE

TABLE 2

DOD RELIES UPON A COMPLEMENTARY TECHNOLOGY BASE

ACTIVITIES INVOLVED ARE:

- DOD LABORATORIES AND CONTRACTORS
- NASA LABORATORIES AND CONTRACTORS
- PRIVATE INDUSTRY THROUGH IR&D
- UNIVERSITY RESEARCH

NASA HAS A VERY LARGE ROLE IN MEETING DOD NEEDS

TABLE 3

PRESENT RELATIONSHIP BETWEEN DOD AND NASA

A. BOTH AGENCIES CONDUCT AERONAUTICAL RESEARCH

B. NASA PERSONNEL ASSIST DOD IN ALL PHASES OF AIRCRAFT DEVELOPMENT

C. DOD MAKES EXTENSIVE USE OF NASA EXPERIMENTAL FACILITIES

D. COOPERATIVE DEVELOPMENT AND USE OF MAJOR NEW AERO RESEARCH FACILITIES

E. DOD RELIES UPON UNIQUE NASA FLIGHT SIMULATION CAPABILITIES

F. MANY NASA/DOD JOINT PROGRAMS IN AERONAUTICAL TECHNOLOGIES

G. DOD USES NASA CIVIL AIRCRAFT TECHNOLOGY FOR UTILITY AND TRANSPORT AIRCRAFT

TABLE 4

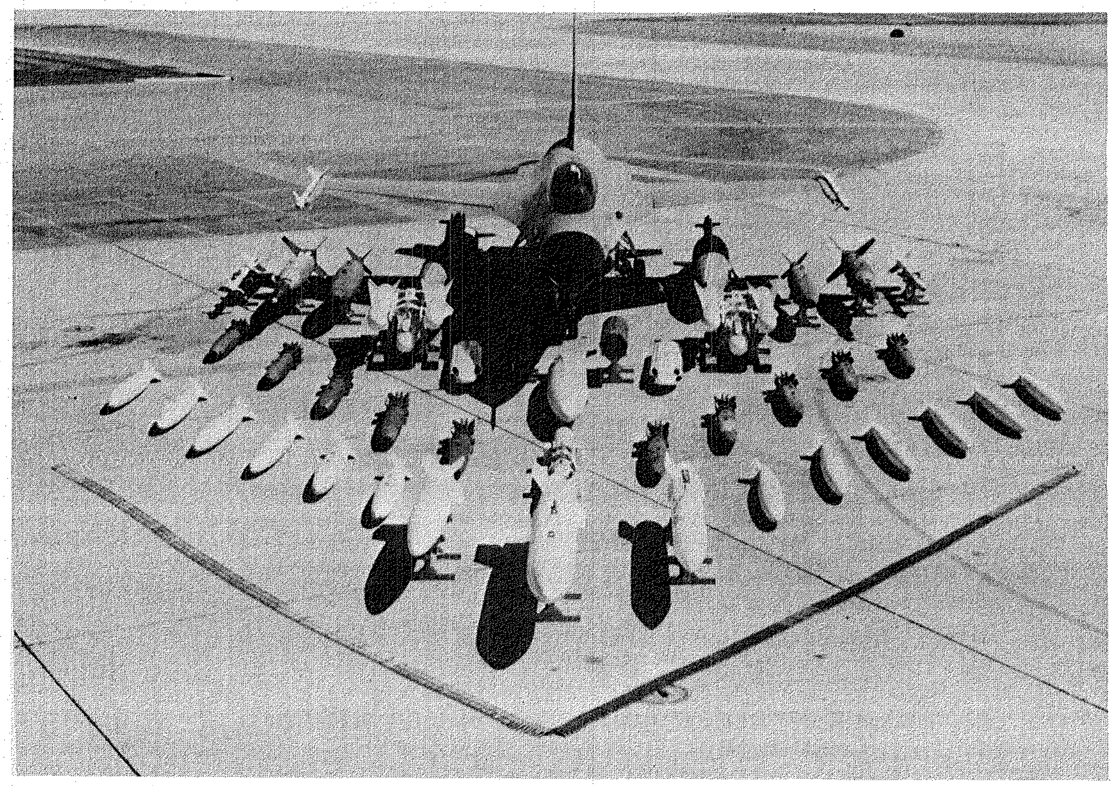

FIGURE 1 F-16 with Ordnance

WAYS FOR NASA TO CONTINUE AND INCREASE ASSISTANCE TO DOD

A. SUSTAIN HIGH INTEREST AT THE LEADING EDGE OF MILITARY AERONAUTICS

B. CARRY TECHNOLOGY DEVELOPMENT THROUGH THE VALIDATION PHASE

C. EXPAND FLIGHT SIMULATION ACTIVITIES AND CAPABILITIES

D. CONTINUE PRESENT NASA – DOD RELATIONSHIPS

TABLE 5

SUMMARY AND CONCLUSIONS

A. NASA AERONAUTICS TECHNOLOGY DEVELOPMENT IS VITAL TO DOD

B. ADVANCED TECHNOLOGY, POTENTIALLY APPLICABLE TO MILITARY AIRCRAFT, MUST BE UNDERTAKEN BEFORE OBVIOUS REQUIREMENTS APPEAR

C. FLIGHT VALIDATION OF NEW TECHNOLOGY IS NECESSARY

D. JOINT PROGRAMS OF MUTUAL INTEREST MUST BE PURSUED

E. CIVIL AIRCRAFT TECHNOLOGY IS IMPORTANT TO DOD

F. EXPANSION OF NASA FLIGHT SIMULATOR CAPABILITY WOULD HELP DOD

TABLE 6

THE EVOLUTION OF THE ROLE OF NACA AND NASA IN AERONAUTICS AND NASA'S AERONAUTICS CAPABILITIES

Dr. Walter B. Olstad
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National Aeronautics and Space Administration

There are two sets of information that I am going to try and leave with you. The first has to do with the evolution of the role of NACA and NASA in aeronautics from the beginning of NACA up to the present time. The second has to do with NASA's aeronautics capability. I am going to try and give you an appreciation for that capability. I think I was helped to a great extent by the previous speaker, who made some flattering remarks and talked about some of our capabilities.

I am going to spend a bit of time with Figure 1, which is a kind of timeline.

Prior to 1915, the focus of aviation progress shifted from the U.S. to Europe after the early successes of the Wright brothers, Curtis, and others. The U.S. actually lost its lead in that time and, in fact, some research centers were established in England, Germany, and France, for example. Fortunately, the U.S. government became aware of this situation and decided that something ought to be done. So, in 1915, the National Advisory Committee for Aeronautics was formed, with its membership composed of leaders from government and universities. There were no industry representatives on the committee.

Figure 2 shows the charter for NACA. The emphasis is on the scientific study of the problems of flight and also on their practical solution. The committee was also asked to determine which problems should be experimentally attacked and how to arrive at solutions and practical application. Those were the primary aspects of that NACA charter.

When World War I came along and the NACA was just a committee in Washington, their first budget was something like $5000, and they were unable to use all of it. We have learned better since.

The committee, from what I have read, really did not make any major contributions to the war effort, with one exception. They convened a meeting of all the engine manufacturers and the procurement officers of the services to discuss the problems of aircraft power plants. The meeting brought into sharp focus the problems involved in obtaining more powerful and more reliable engines for military aircraft and developed an arrangement whereby the Society of Automotive Engineers became involved in providing assistance in solving aircraft powerplant problems. A year later, the NACA recommended the establishment of the Aircraft Production Board. A major U.S. contribution to aviation during World War I was the development of the Liberty engine.

Much of the effort of the committee at that time was directed toward the establishment of the first research center. Originally it was to be colocated with the Army and with the Navy, all to do R&D at the same place. They chose Langley Field as the location and then the Army decided no, we really want to do our R&D at McCook Field, which later became Wright-Patterson. The Navy decided no, they would stay across Hampton Roads in Norfolk. There was an Army airfield at Langley, of course.

On June 11, 1920, the Langley Memorial Aeronautical Laboratory was formally dedicated. There were three buildings at that time--one housing a tunnel, one an engine dynamometer, and another a research lab.

Immediately after World War I, there was considered to be two major problems in aeronautics. The first was aerodynamics, and the second was power plants. NACA chose to work in aerodynamics, and the National Bureau of Standards took on the role in power plants. Actually, they already had that role prior to the establishment of NACA. Also, the committee felt that the industry had excellent facilities and so it really wasn't necessary for the committee to concentrate on aircraft power plants at that time.

In 1921, Max Munk joined Langley and brought to it his scientific expertise and his aggressiveness. He was a very prolific researcher, authoring or coauthoring some 57 reports in a period of 5 years. Perhaps more importantly, he was the driving force behind the development of the Variable-Density Wind Tunnel, which was a major advance in wind tunnel capability at that time. It gave the Langley researchers a capability for controlling Reynolds Number and led to the development of the NACA series of airfoils, which was one of the major contributions.

In 1926, the Air Commerce Act was passed. This was a result of a great deal of debate starting in 1919. The Air Commerce Act established the national aviation policy and also formed the Bureau of Aeronautics within the Commerce Department. It kept NACA separate from and independent of any other department and kept it as primarily a research organization. There was quite a bit of pressure to bring NACA under the Commerce Department at that time. It was really a lack of agreement on how to do that that kept it from happening and retained NACA's independent status.

In 1927, Lindbergh crossed the Atlantic in the Spirit of St. Louis. This event really brought aviation to the fore in the U.S. and

made people aware of it and proud of it and willing to spend money on it. The Propeller Research Tunnel was also developed at Langley that same year, which allowed the development of the NACA cowling. This cowling work had been requested first by the military and then by the industry. It turned out to be a very interesting example of government-industry cooperation in which NACA did the research and developed cowling designs. However, they sent the blueprints out to industry for their comments and recommendations and then worked rather closely with the industry.

That activity led to a flight demonstration. It was certainly not prototyping, but it was a flight demonstration of cowling technology and allowed it to be rather easily and quickly incorporated into actual aircraft.

The cowling was a major success and the committee capitalized on that success. As a result they were able to advocate successfully the Full-Scale Wind Tunnel and the Seaplane Towing Tank, which were built at Langley in 1930.

In the late 1920s, industry representatives began to serve on NACA technical subcommittees and annual industry conferences were held at Langley. They used to get on the boat in Washington, come down the Chesapeake, stop at old Point Comfort, spend the night, go into Langley for the day, and then get back on the boat to return to Washington. Those conferences later came to be called inspections and became quite a regular thing.

However, NACA generally refused to test industry models in their facilities. Industry would come with a request and NACA would respond, "No, we just don't wish to show favoritism to any one company." Almost all of their work was done at the request of the military. There was a very strong military relationship then.

However, in 1931, after the Full-Scale Tunnel was built and operating, a policy was established so that industry models could be tested on a fee basis and without any guarantee regarding proprietary rights. All the data were available to the government and to everybody else.

This tended to favor the large, established companies, because it could cost quite a bit to get to the point where a model could be built for testing. In fact, a lot of the way that NACA and, in fact, NASA works with the industry does tend to favor the large, established companies. It is difficult not to. It is certainly difficult to find the innovative individual. NASA certainly can't locate him. He has to find NASA, and sometimes it is rather expensive for him to take advantage of our capability.

In 1938, there was another act, the Civil Aeronautics Act, which split the Bureau of Aeronautics in the Commerce Department into the CAB and the Civil Aeronautics Administration, which later became the FAA. Again, NACA remained independent and again there was pressure to bring NACA in with these other organizations and put them under some other department, but that was resisted. At that time the voice of commercial aviation as opposed to military aviation was strengthened on the committee because the heads of these two newly formed organizations became members.

In the late 1930s, there was a growth of German aviation activity, also some Soviet activity. The Germans were rapidly building facilities. They employed more scientists and engineers in their laboratories than did NACA, and in general they were better educated than those employed by NACA. This led to a great deal of concern, and the Special Committee on Future Research Facilities was established to look into the situation. The special committee came up with what they called a mobilization plan in 1939, in which it recommended the establishment of a second NACA laboratory. The reasons were, first, to relieve the workload at Langley; second, to disperse the facilities in the event of attack; third, to locate close to a major segment of industry that was now on the West Coast; and fourth, to locate close to available power. The Ames Aeronautical Laboratory was approved and began research in October 1940.

Also in 1939, NACA expanded its subcommittee structure adding a great many industry representatives. So, as time went on the influence of industry on the committee was strengthening, although there were still no industry representatives on the main committee.

In 1940, the Aircraft Engine Research Laboratory was approved, which was to become Lewis. It was something of an afterthought. NACA, as I mentioned, had not been in the engine game. They had, back in the beginning, opted out of it. The recognition came that NACA really needed to do something and that it needed a laboratory. It was decided that it would be in Cleveland in order to be close to the engine industry. Research began there in June 1942.

During World War II, the great bulk of the NACA effort was devoted to cleanup and testing of prototype military aircraft. Every aircraft and engine used in World War II was tested and/or approved in NACA facilities. There was little fundamental research going on due to the press of the work of the day. NACA worked directly with industry. There were many industry representatives on-site. The idea of working through the military first to get to the industry just didn't matter. There was a war going on; there was a war effort. So, the relationship among the industry, the military, and the NACA really grew close.

The NACA manpower quadrupled during this period, and the industry and the military grew even faster.

At the end of the war, the Administration put together a National Aeronautics Research Policy in which it was stated that NACA was responsible for fundamental research, industry for development, and military for evaluation. There was general agreement on those points although there was no general agreement on what those things meant and where the boundaries were. Also, three industry representatives were named to the main committee for the first time.

In the late 1940s and 1950s, the challenge of supersonic flight was a real impetus to the U.S. aeronautics program. It was partially based on a U.S. response to German progress made during the war, also, I think, partially based on perceived prestige and security issues associated with aviation leadership. It led to the research aircraft program, or the X-series of aircraft, which was a joint NACA-military-industry effort. It worked very much like the wartime effort--very

close cooperation among the three partners on that activity. Again, industry people at the centers--it really didn't matter who the sponsor of the activity was--everybody was working on the same team.

In 1949, the NACA High-Speed Flight Research Center was opened. Of course, that has since become Dryden. Also in 1949, the Unitary Wind Tunnel Plan Act was enacted with two titles. Title I was for the building of three wind tunnels for NACA--supersonic tunnels at Langley, Ames, and Lewis. That got changed somewhat because Ames ended up with more than one. According to the intent of the Act, those wind tunnels were primarily for industry use. The industry had a very powerful influence in that Act and the wording of it. Title II led to the establishment of the Air Engineering Development Center, later to become the Arnold Engineering Development Center, in Tullahoma, Tennessee.

In the early 1950s, the first transonic tunnels were developed. Rockets were used for transonic research. The first V/STOL demonstration aircraft was developed. There was quite a bit of activity going on at that time, with all kinds of facilities.

In 1958, of course, the Space Age dawned and NASA was formed. This eliminated the committee structure and led to a very different kind of organization than what was the NACA organization. The administrator now was an individual who was really preoccupied with space, because that became the key thing in the program. However, the organization was still independent. It still played no regulatory role.

The NASA charter is shown in Figure 3. Al Lovelace spoke about this the other day. There is still an emphasis on the fundamentals of the scientific aspect of the problem of flight, as well as an emphasis on the practical application. There is also, now, an emphasis on preserving U.S. leadership in aviation and also a link with the military.

As a result of entering the Space Age and the concentration on that activity, both the manpower devoted to aeronautics and the aeronautics budget within NASA were cut to half their previous levels. Also about this time, the divergence between civil and military requirements for aircraft began to show up, which is an interesting factor in the role that NASA now plays.

In the mid-1960s and early 1970s, the NASA aeronautics capability was built back to about two-thirds of the previous peak manpower.

In 1968, NASA bagan some long-range studies of commercial air transportation. These were taken on in cooperation with the FAA and with industry and led to an emphasis on technology for commercial transport.

In 1975, the Aircraft Energy Efficiency, or ACEE, program was approved, and in some respect this represented a different role. Formally, the Senate requested NASA to provide a plan for improving the efficiency of commercial transport aircraft. Of course they were interested in fuel economy, but they were also interested in the economic and competitive wealth of the commercial transport industry.

NASA and industry testified that NASA should go beyond the traditional R&T bounds in this activity and extend to the point where

results can be readily applied by industry with relatively small risk in terms of development cost and schedule. Some elements of ACEE, but clearly not all of them, represent product improvement activities, such as the Engine Components Improvement program. Most elements of ACEE remain well within the traditional areas.

We are about halfway through the ACEE program now, and I feel that it is already proving to be highly successful. We can already point to quite a few accomplishments. The payback from ACEE will be many times the investment. However, I would note that the Administration--you can read OMB there--considers ACEE a one-of-a-kind solution to a particular problem that cropped up and not necessarily a precedent.

Figure 4 shows some slow, early growth in manpower and then, just prior to the 1940s, or right around 1940, Ames got going, and in 1942 Lewis got going. There was, of course, the tremendous increase in manpower during World War II. Then, there was further growth after the war as NACA got into the supersonic program. With the beginning of the Space Age, in the late 1950s, the manpower dropped roughly to half its previous level. Then, there was a recovery over an 8- to 10-year period to the current level, which is about two-thirds of the peak.

I might point out that NASA now has more facilities. There is a greater diversity in the kinds of things we do, the number of disciplines we deal with. As a result, NASA manpower is thin. We are certainly spread more thinly than we were at the peak, obviously.

The funding history shown in Figure 5 looks like a spectrum of some kind. Those are 1980 dollars; so, this has been adjusted for inflation. There were major increases during World War II and during the commitment to the supersonic flight program. The spike at about 1950 represents the Unity Plan Wind Tunnel Act. During the late 1950s and early 1960s, the budget dropped to about one-half the previous level. During the late 1960s, it began growing again to where it has even passed the previous peak.

There are a number of things going on, of course. Our manpower is less. We are depending more on industry, more on contracting our activities. As I mentioned, there is a greater diversity of discipline areas. There is more emphasis on systems kinds of activities and the use of more sophisticated tools. Those tools cost more and also cost more to operate and maintain. There is a need to bring technology closer to application for reasons that have been discussed by other speakers. And program costs have increased faster than the inflation rate.

The foregoing provides a background on how we got to today. Now, I would like to talk some about the NASA capability in aeronautics.

Unfortunately, we have some numbers on Figure 6 that aren't as meaningful as they should be. What these numbers represent in terms of the staff are the total numbers at those centers. We had meant to give you the numbers devoted to the aeronautics programs only. I am going to read the proper numbers to you and also provide them to you in a separate handout.

The Civil Service staff devoted to aeronautics at Ames is 655 out of a total of 1645. At Langley, it is 1482. So, roughly half of the Langley Civil Service staff is directly devoted to aeronautics. At Lewis it is 2111, and at Dryden it is 301.

There is some additional manpower in the aeronautics program not located at those four centers. There are, of course, people at headquarters and a number over at Wallops. The total working directly on the aeronautics program is 3772 in FY 1980.

The numbers in the right column are correct. Those are what we call the R&D dollars. They do not include construction of facilities, and they do not include salaries and overhead.

NASA working relationships are shown in Figure 7. We work with other government organizations as shown. There are many interfaces, a lot of interaction, informally. There is a lot of formal interaction. There are coordinating committees of many different kinds. There are several ways that we work with industry: the advisory committees, technical symposia, workshop conferences, contracts, obviously a very important way we work with industry. We also work with the universities. I should have said more about that earlier. There always has been a tie with the universities. The first chairman of the NACA was Brig. Gen. George Scriven, U.S. Army. Since then all chairmen were civilians. The second chairman was Professor Durand of Stanford and it is interesting that he also received the first contract. No one worried about a conflict of interest because he was obviously the most qualified individual.

Now, I want to talk about the individual centers. We will start with Ames. Somewhat arbitrarily we have grouped their capabilities in the four areas shown in Figure 8. The same four areas are shown on the left of the matrix in Figure 9. The column headings represent application areas--generic, general aviation, etc. Where there is a solid symbol, obviously, there is a major emphasis. Where there is an open symbol the activity is applicable but is not the major role or major emphasis at that center.

Figure 10 illustrates work in the theoretical and computational analysis area. This particular illustration shows both wind tunnel and calculated flow fields. These are calculations performed on the Illiac IV. Computational flow simulation is a real strength at Ames.

In the wind tunnel experimental investigations area, Figure 11 shows an example of V/STOL configuration work with a model tested in the 11-Foot, 40- by 80-Foot, and 12-Foot Wind Tunnels. Additional activities in the 11-Foot tunnel are shown in the lower half of the figure. One of the really nice features about the major Ames facilities is that the same model can be through the speed range from low subsonic to supersonic. Also the power costs are less at Ames than at other centers.

Figure 12 illustrates the simulation and human factors area with a picture of the Flight Simulator for Advanced Aircraft. It represents only a portion of the simulation capability of Ames.

In the flight systems research and operations area there are a number of efforts, some of which are shown in Figure 13. One of these is the tilt rotor research aircraft program. There are two of these

aircraft. One of them is being refurbished after being tested in the 40- by 80-Foot Wind Tunnel. The other is to be delivered shortly to Dryden, where it will undergo additional envelope expansion flights. There are other flight facilities, like the quiet, short-haul, research aircraft (QSRA) and the rotor-systems research aircraft (RSRA), associated with Ames as well.

At Dryden there are a number of areas of activity, as shown in Figure 14. The activities/applications matrix for Dryden is shown in Figure 15.

Flight test techniques are illustrated in Figure 16. This shows one of the calibrated cones mounted on the nose of an aircraft, used to obtain flight data to compare with the wind tunnel data in terms of transition Reynolds number; just one of many examples of flight test techniques activities that go on at Dryden.

The flight test instrumentation area is illustrated in Figure 17. This is an example of the HIMAT (Highly Maneuverable Aircraft Technology) vehicle in the flight structural loads rig test equipment. The HIMAT is a particularly interesting vehicle because aeroelastic tailoring was used in its design in an attempt to arrive at the optimum configuration under deflection due to flight loads. It is a remotely piloted vehicle and is one of a couple of remotely piloted vehicles at Dryden; the HIMAT and the DAST, (Drone for Aeroelastic and Structural Tests) (Figure 18). We work with these so that we can do higher-risk flight testing.

Langley Research Center capabilities are shown in Figure 19 and the matrix is shown in Figure 20.

Aerodynamics and flight mechanics are illustrated in Figure 21. This shows some activities to further improve wind tunnel facilities, magnetic balance work, and crygenic wind tunnel technology. Under this category are the many major wind tunnel facilities at Langley.

The area of aeroelasticity is shown in Figure 22. We use tunnels like the Transonic Dynamics Tunnel, which was mentioned as the 19-Foot Transonic Freon Tunnel. It provides a very unique capability for doing flutter research. Flutter suppression work as a military model is illustrated here.

Figure 23 illustrates the materials, structures, and dynamics area. These are examples of the kinds of things that go on--control, environmental effects, which all feed into safety, relability, and economy.

The electronics, avionics, and controls area is shown in Figure 24. Shown here is the new airlab facility. Other examples of the activities in this area are simulators and the TCV (Terminal Configured Vehicle) aircraft.

Figure 25 provides an example of efforts in airframe propulsion integration. The 8-Foot Transonic Pressure Tunnel is shown. The 16-Foot and V/STOL Tunnels are also used.

Acoustics and noise reduction activities are shown in Figure 26. The Aircraft Noise Reduction Laboratory and several scenes within that facility are illustrated.

The final capability area at Langley is in vehicle systems technology. Shown in Figure 27 is the Differential Maneuvering Simulator.

It is a unique facility that has certainly gotten a lot of use in support of the military. I should also mention an important capability at Langley that is not listed in Figure 19, and that is Langley's capability in computer-aided design.

The four primary capability areas for the Lewis Research Center are shown in Figure 28. They also appear again in the matrix presented in Figure 29.

The first capability area illustrated is theoretical and computational analysis (see Figure 30). This is an area of great promise and recent growth. Computers are now getting powerful enough and we are getting smart enough in our use of the computer to work on the very difficult internal flow problems. Shown is an experimental setup and a comparison of analysis against experiment.

Fundamental research is illustrated in Figure 31. This is an example of advanced diagnostics using a laser velocimeter. Again, and this applies to all the centers, there has been a breakthrough in measurement techniques in the last few years with improvements in electronics and lasers, which allow nonintrusive diagnostics and measurements in the flow field rather than just on the surface of a model. This is very important in propulsion research.

Advanced turbine work is shown as an example of component R&T in Figure 32. There are compressor rigs, combuster rigs, power transmission facilities, high-pressure hot section facilities, and the like for doing component technology R&T at Lewis.

The engine and propulsion system R&T example shown in Figure 33 is of the development and test of an advanced control theory for the F-100 engine. The static engine test stands, altitude facility, propulsion tunnels, and icing research facility, among others, are used in this kind of activity.

So, there is quite an overall capability available in NASA. A rough estimate is that there is a $3-$4 billion replacement value for the NASA aeronautical facilities. There is in-house expertise in all of the disciplines mentioned from fundamental research up to systems technology.

Figure 34 displays the capability in an overall matrix that shows a rather complete coverage in critical areas.

Thank you.

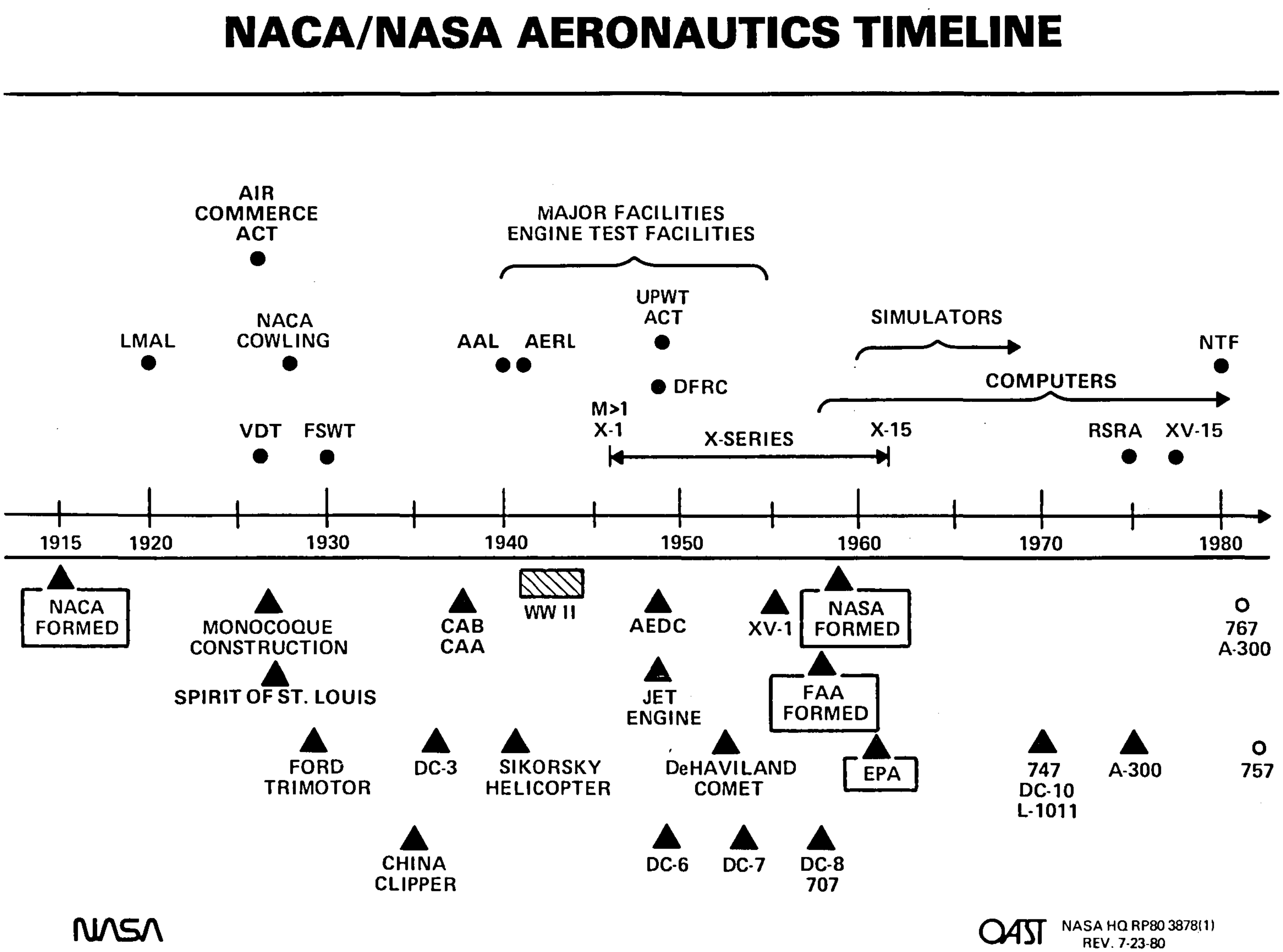

NACA/NASA AERONAUTICS TIMELINE
AIR COMMERCE ACT
MAJOR FACILITIES
ENGINE TEST FACILITIES
LMAL
NACA COWLING
AAL
AERL
UPWT ACT
DFRC
SIMULATORS
NTF
COMPUTERS
VDT
FSWT
M>1 X-1
X-SERIES
X-15
RSRA
XV-15
1915
1920
1930
1940
1950
1960
1970
1980
NACA FORMED
MONOCOQUE CONSTRUCTION
SPIRIT OF ST. LOUIS
CAB CAA
WW II
AEDC
JET ENGINE
XV-1
NASA FORMED
FAA FORMED
767 A-300
FORD TRIMOTOR
DC-3
SIKORSKY HELICOPTER
DeHAVILAND COMET
EPA
747 DC-10 L-1011
A-300
757
CHINA CLIPPER
DC-6
DC-7
DC-8 707
NASA HQ RP80 3878(1)
REV. 7-23-80

FIGURE 1

NACA MISSION CHARTER

IT SHALL BE THE DUTY OF THE ADVISORY COMMITTEE FOR AERONAUTICS TO SUPERVISE AND DIRECT THE SCIENTIFIC STUDY OF THE PROBLEMS OF FLIGHT, WITH A VIEW TO THEIR PRACTICAL SOLUTION, AND TO DETERMINE THE PROBLEMS WHICH SHOULD BE EXPERIMENTALLY ATTACKED, AND TO DISCUSS THEIR SOLUTIONS AND THEIR APPLICATION TO PRACTICAL QUESTIONS.

NASA

OAST NASA HQ RP80 4252(1)
7-23-80

FIGURE 2

NASA MISSION CHARTER

THE AERONAUTICAL . . . ACTIVITIES OF THE U.S. SHALL BE CONDUCTED SO AS TO CONTRIBUTE MATERIALLY TO ONE OR MORE OF THE FOLLOWING OBJECTIVES:

(1) THE EXPANSION OF HUMAN KNOWLEDGE OF PHENOMENA IN THE ATMOSPHERE . . .

(2) THE IMPROVEMENT OF THE USEFULNESS, PERFORMANCE, SPEED, SAFETY, AND EFFICIENCY OF AERONAUTICAL VEHICLES . . .

(5) THE PRESERVATION OF THE ROLE OF THE U.S. AS A LEADER IN AERONAUTICAL . . . SCIENCE AND TECHNOLOGY AND IN THE APPLICATION THEREOF TO THE CONDUCT OF PEACEFUL ACTIVITIES WITHIN AND OUTSIDE THE ATMOSPHERE

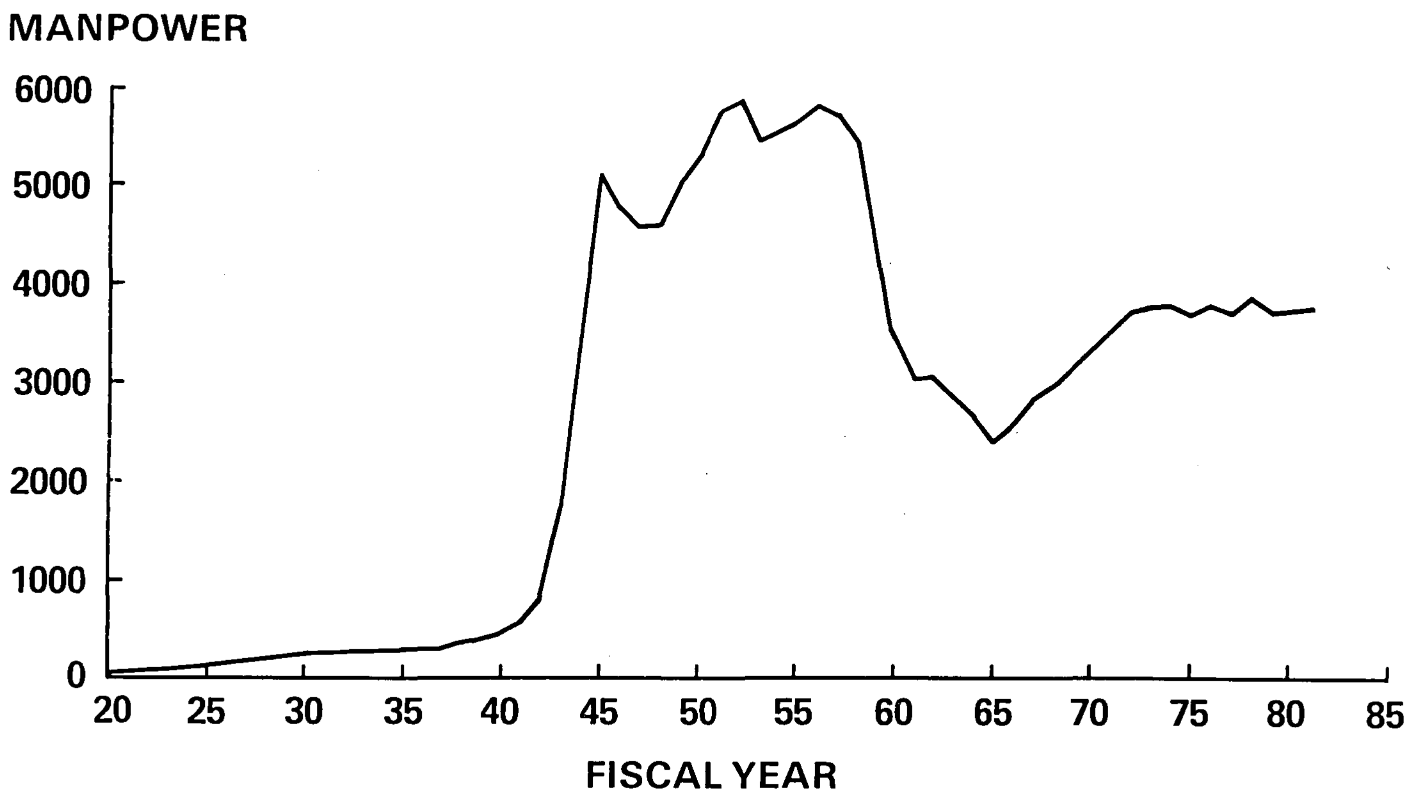
(6) THE MAKING AVAILABLE TO AGENCIES DIRECTLY CONCERNED WITH NATIONAL DEFENSE OF DISCOVERIES THAT HAVE MILITARY VALUE OR SIGNIFICANCE AND THE FURNISHING BY SUCH AGENCIES INFORMATION AS TO DISCOVERIES WHICH HAVE VALUE OR SIGNIFICANCE TO NASA

NASA HQ RP80 4251(1)
7-23-80

FIGURE 3

AERONAUTICS MANPOWER HISTORY

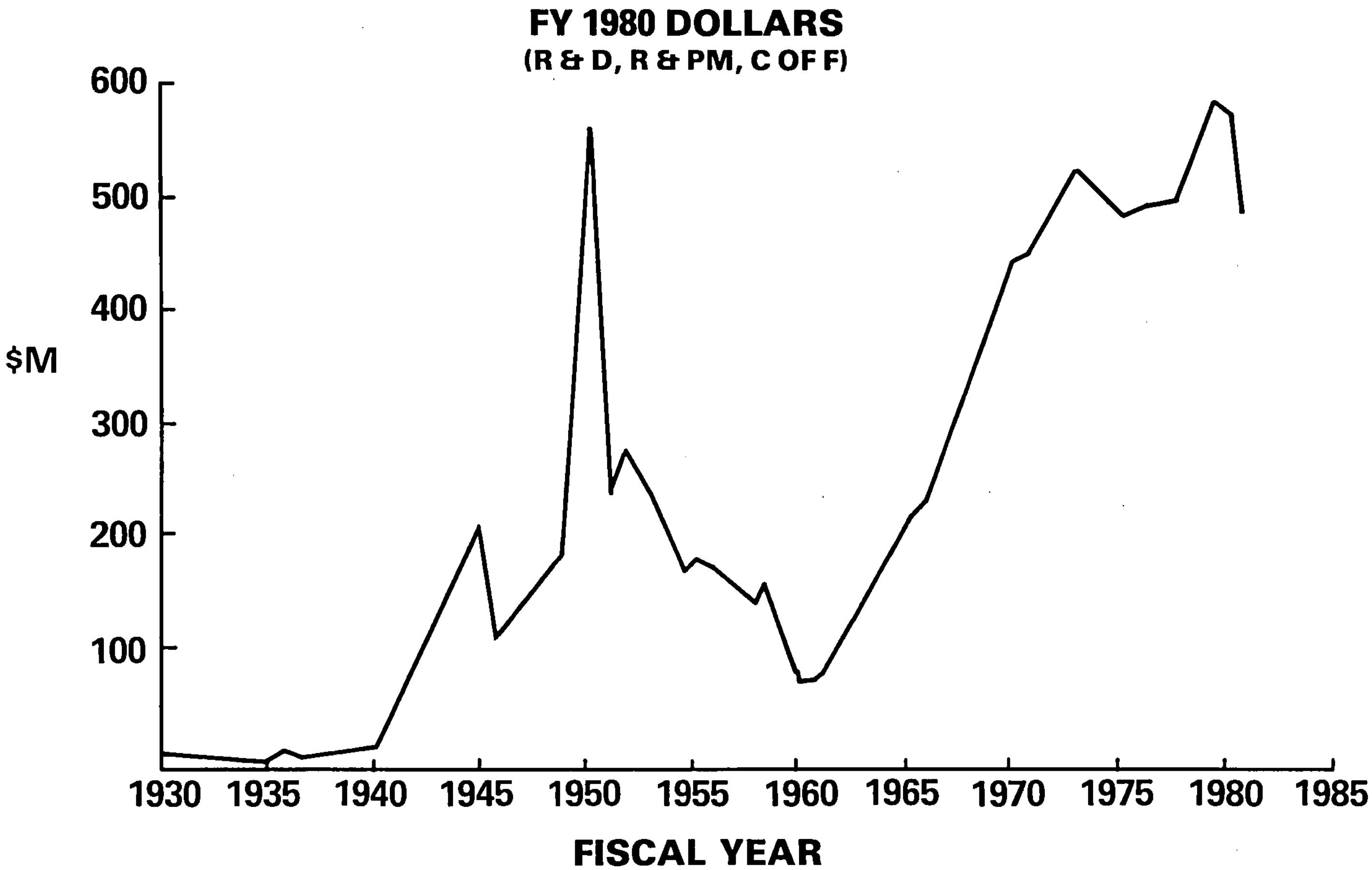
DIRECT CIVIL SERVICE



NASA HQ RP80 4263(1)
7-23-80

FIGURE 4

AERONAUTICS FUNDING HISTORY



NASA

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7-23-80

FIGURE 5

NASA AERONAUTICS PROGRAM RESOURCES

FY 1980

CENTER	CIVIL SERVICE STAFF	SCIENTIFIC & ENGINEERING	R & D ($M)
AMES	1,645	829	49.4
DRYDEN	457	179	12.3
LANGLEY	2,877	1,276	118.1
LEWIS	2,822	1,044	117.4
	7,801	3,328	297.2

NASA

FIGURE 6

OAST NASA HQ RP80 4239(1)
7-23-80

NASA WORKING RELATIONSHIPS

OTHER ORGANIZATIONS
- FAA
- DOT
- AIR FORCE
- NAVY
- ARMY
- EPA
- OMB
- OSTP

UNIVERSITIES (FY 80)
- ARC — $3422K
- DFRC — $ 220K
- LARC — $6391K
- LERC — $4795K

NASA AERONAUTICS PROGRAM

INDUSTRY
- ADVISORY COMMITTEES
- TECHNICAL SYMPOSIA
- WORKSHOPS, CONFERENCES
- CONTRACTS
- PERSONAL CONTACTS

NASA

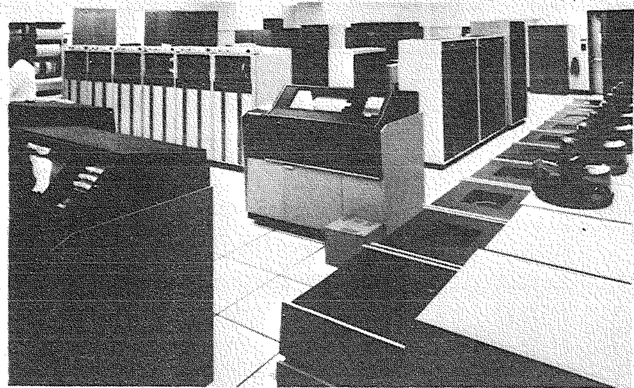
OAST

NASA HQ RP80 4264(1)
7-23-80

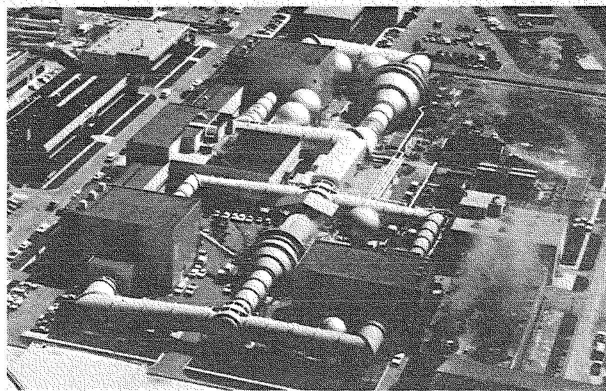
FIGURE 7

Ames Research Center

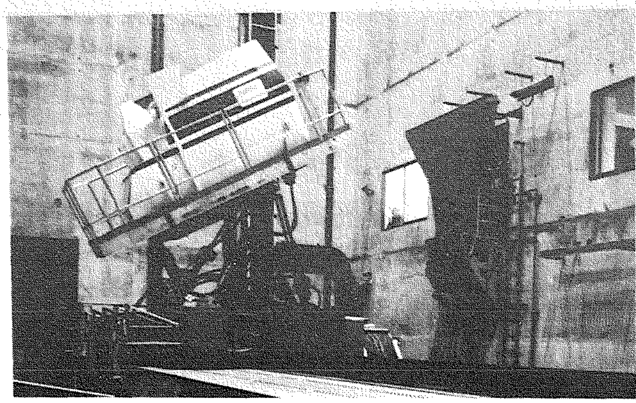
AERONAUTICAL CAPABILITIES



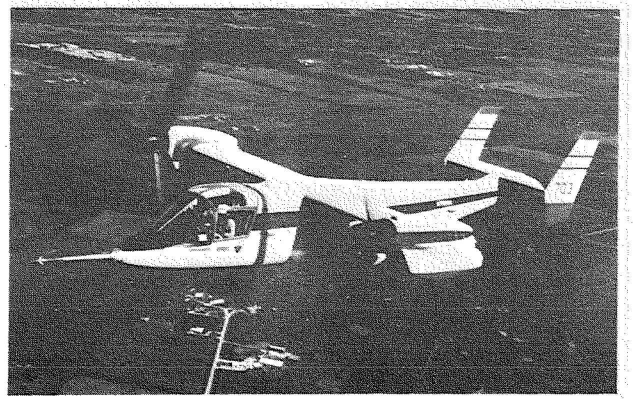
THEORETICAL AND COMPUTATIONAL ANALYSIS



WIND TUNNEL EXPERIMENTAL INVESTIGATIONS



SIMULATION AND HUMAN FACTORS RESEARCH



FLIGHT SYSTEMS RESEARCH AND OPERATIONS

FIGURE 8

CENTER CAPABILITY AREAS/ POTENTIAL APPLICATIONS

AMES RESEARCH CENTER

POTENTIAL APPLICATIONS / CAPABILITY AREAS	AERONAUTICS					
	GENERIC	G/A	V/STOL	ROTOR-CRAFT	COMM. TRANS.	MILITARY
THEORETICAL & COMPUTATIONAL ANALYSIS	●	○	●	●	○	○
WIND TUNNEL EXPERIMENTAL INVESTIGATIONS	●	○	●	●	●	●
SIMULATION & HUMAN FACTORS RESEARCH	●	○	●	●	●	●
FLIGHT SYSTEM RESEARCH AND OPERATIONS	●		●	●	○	○

● MAJOR EMPHASIS OF ACTIVITY

○ ACTIVITY APPLICABLE

NASA

OAST NASA HQ RP80 4266(1) 7-23-80

FIGURE 9

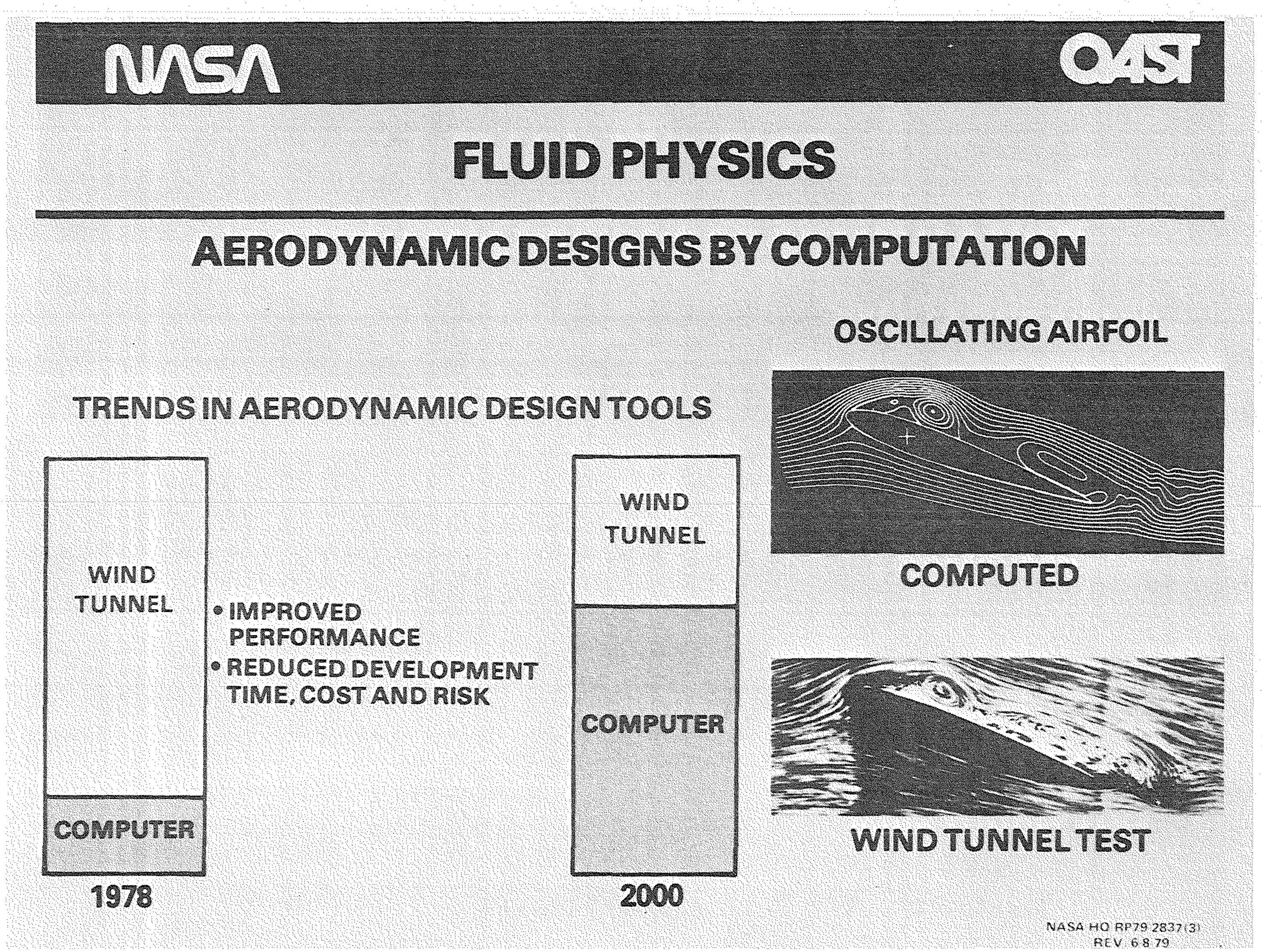

NASA
OAST
FLUID PHYSICS
AERODYNAMIC DESIGNS BY COMPUTATION
TRENDS IN AERODYNAMIC DESIGN TOOLS
WIND TUNNEL
COMPUTER
1978
• IMPROVED PERFORMANCE
• REDUCED DEVELOPMENT TIME, COST AND RISK
WIND TUNNEL
COMPUTER
2000
OSCILLATING AIRFOIL
COMPUTED
WIND TUNNEL TEST
NASA HQ RP79 2837(3)
REV. 6 8 79

FIGURE 10

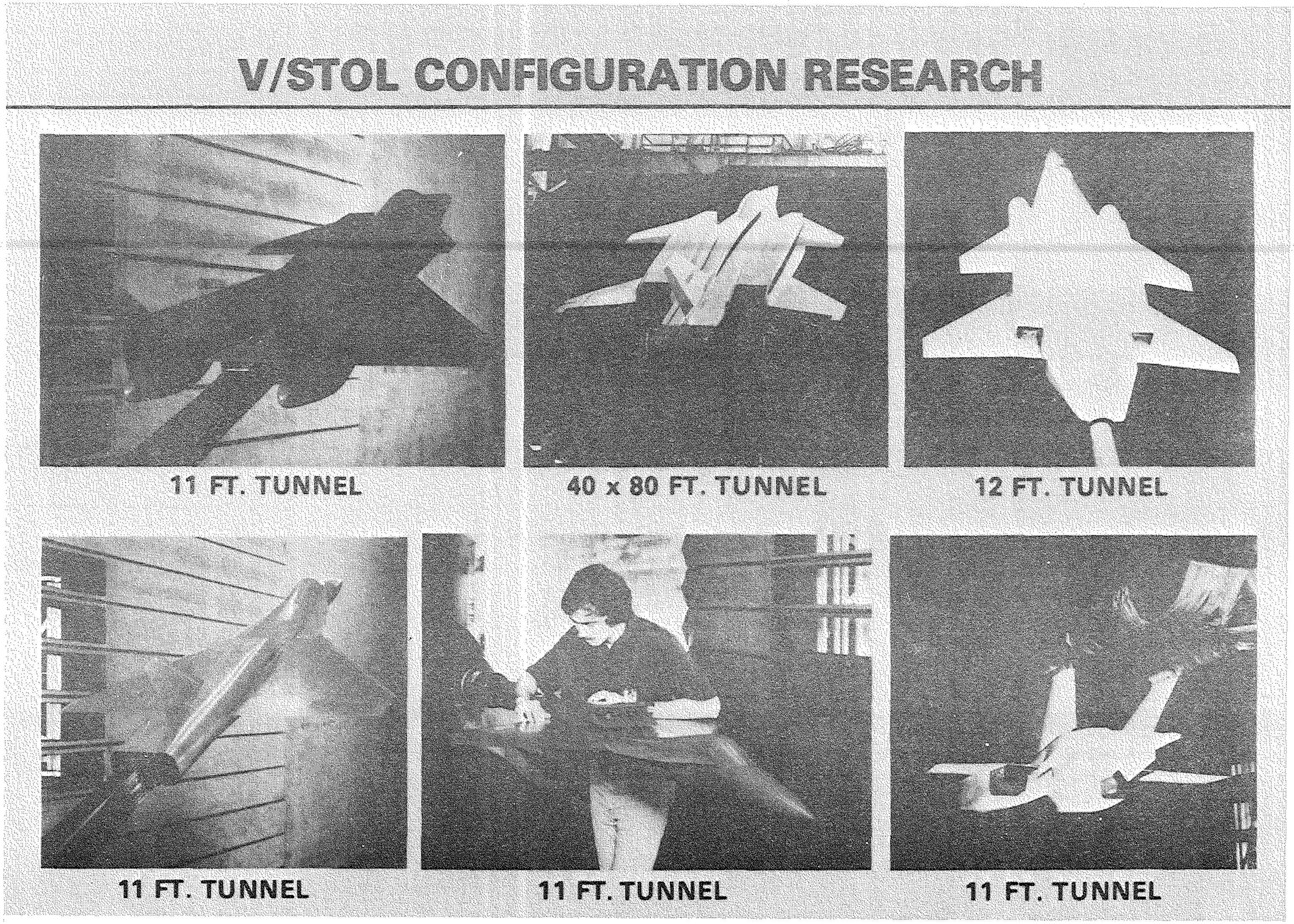

V/STOL CONFIGURATION RESEARCH
11 FT. TUNNEL
40 x 80 FT. TUNNEL
12 FT. TUNNEL
11 FT. TUNNEL
11 FT. TUNNEL
11 FT. TUNNEL

FIGURE 11

FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT

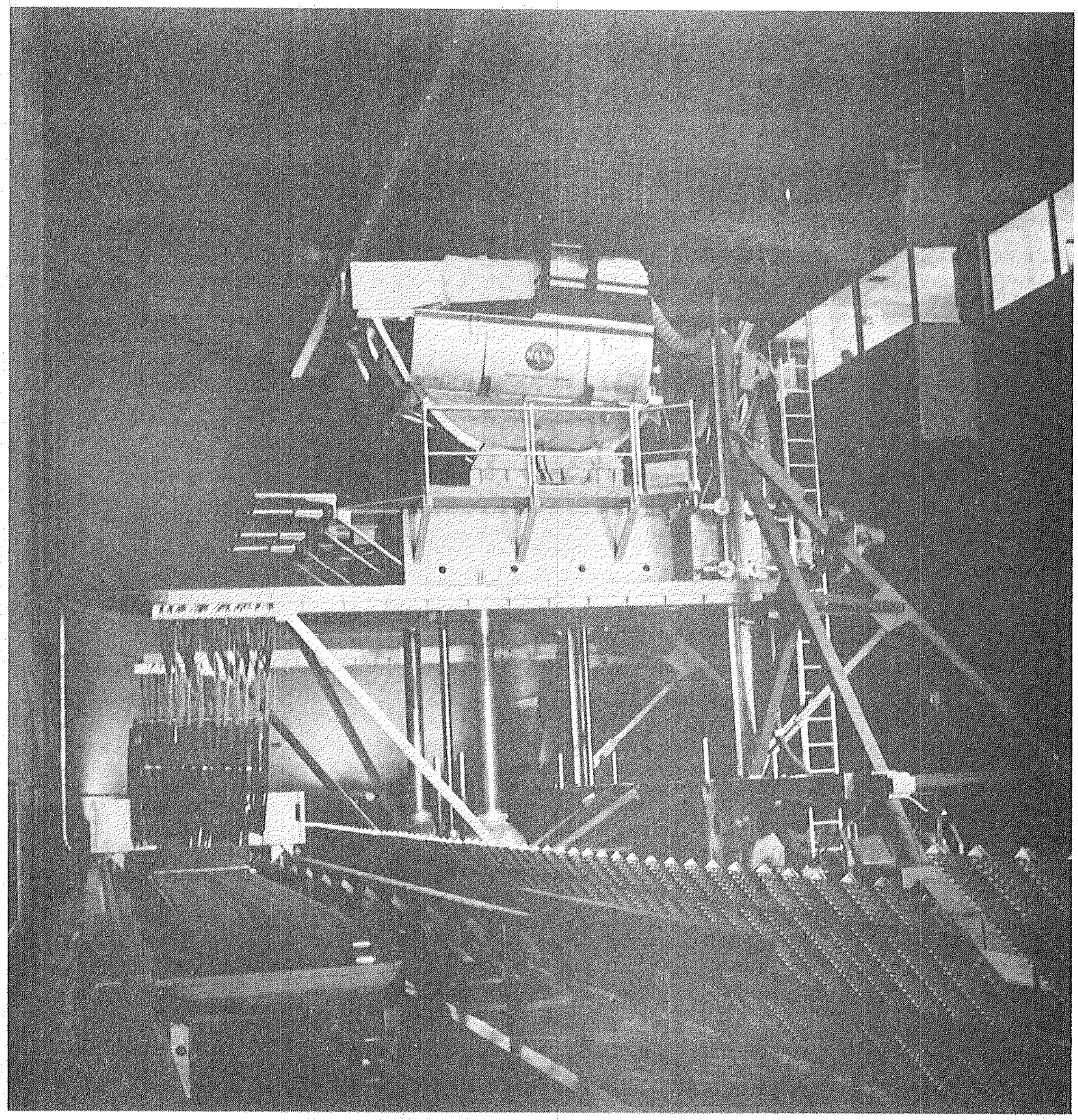


FIGURE 12

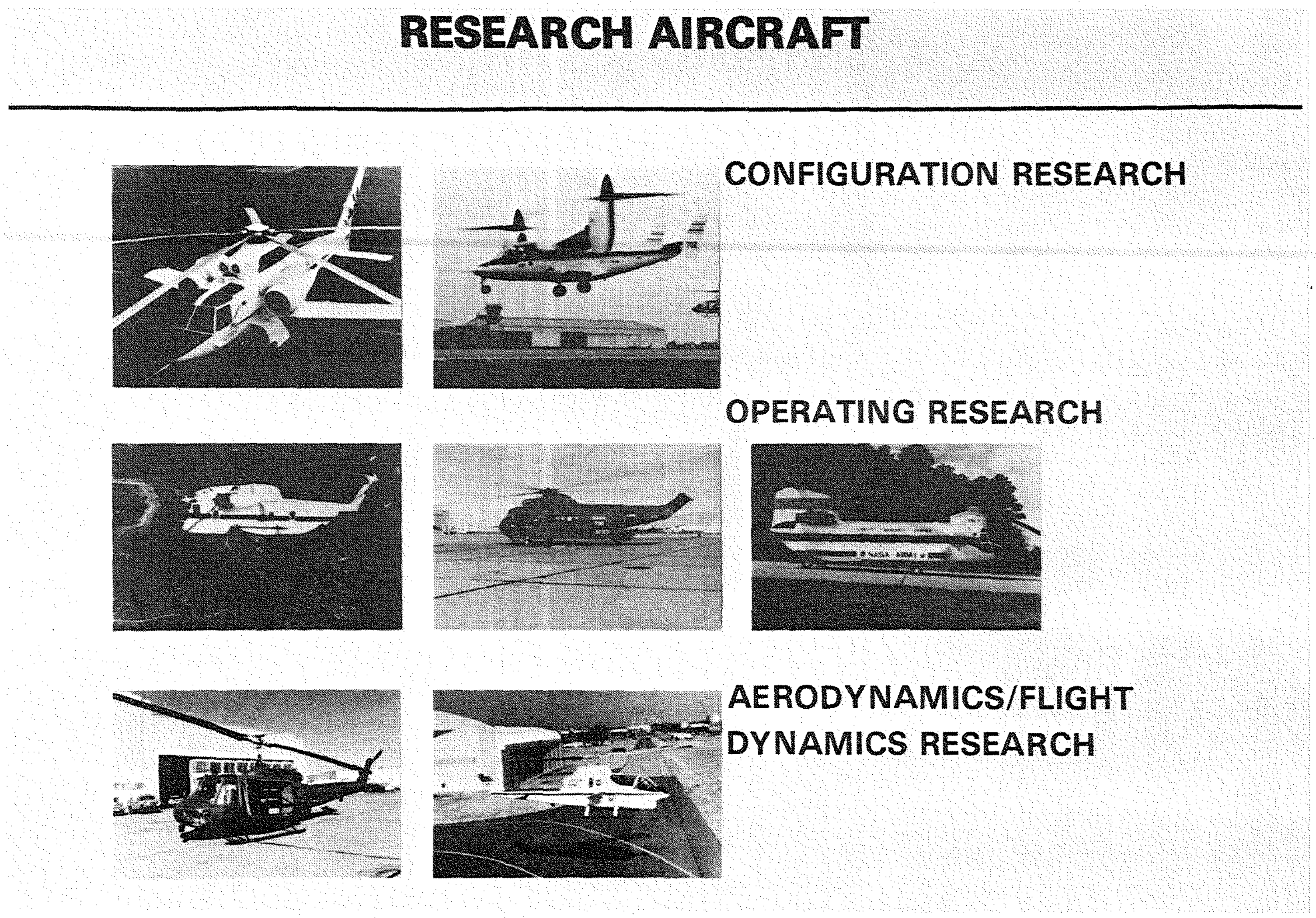

RESEARCH AIRCRAFT
CONFIGURATION RESEARCH
OPERATING RESEARCH
AERODYNAMICS/FLIGHT
DYNAMICS RESEARCH

FIGURE 13

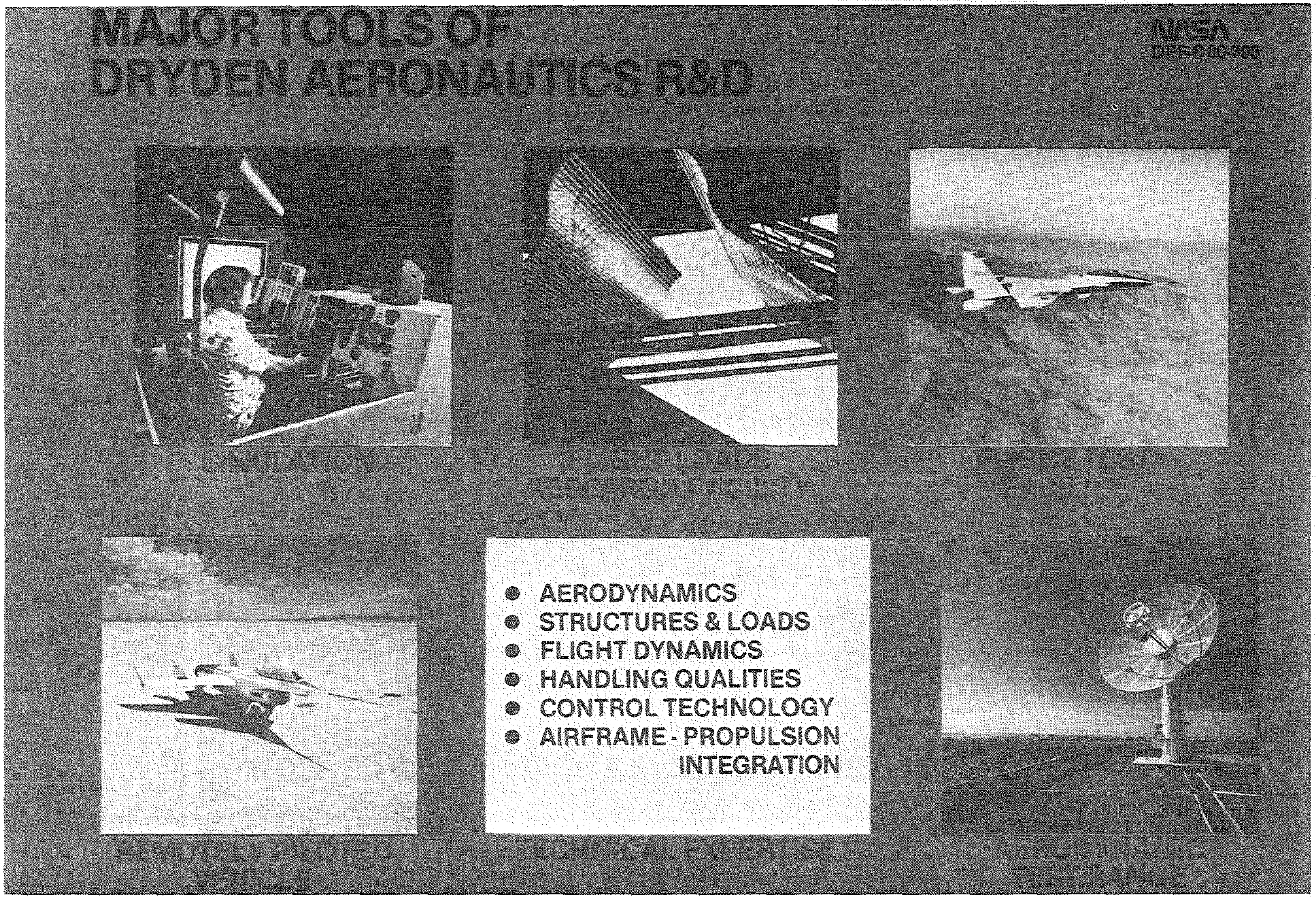

MAJOR TOOLS OF
DRYDEN AERONAUTICS R&D
NASA
DFRC 80-398
SIMULATION
FLIGHT LOADS
RESEARCH FACILITY
REMOTELY PILOTED
VEHICLE
AERODYNAMICS
STRUCTURES & LOADS
FLIGHT DYNAMICS
HANDLING QUALITIES
CONTROL TECHNOLOGY
AIRFRAME - PROPULSION
INTEGRATION
TECHNICAL EXPERTISE
AERODYNAMIC
TEST RANGE

FIGURE 14

CENTER CAPABILITY AREAS/ POTENTIAL APPLICATIONS

DRYDEN FLIGHT RESEARCH CENTER

POTENTIAL APPLICATIONS / CAPABILITY AREAS	AERONAUTICS					
	GENERIC	G/A	V/STOL	ROTOR-CRAFT	COMM. TRANS.	MILITARY
FLIGHT TEST TECHNIQUES	◓	○	●	○	●	●
FLIGHT TEST INSTRUMENTATION	○	○	○	○	●	●
FLIGHT TEST FACILITIES		◓	◓	◓	●	●

● MAJOR EMPHASIS OF ACTIVITY

○ ACTIVITY APPLICABLE

NASA

OAST NASA HQ RP80 4236(1) 7-23-80

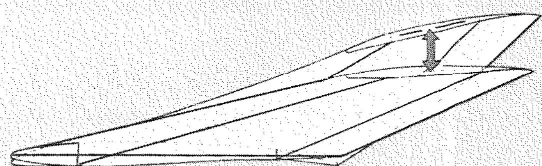
FIGURE 15

FIGURE 16

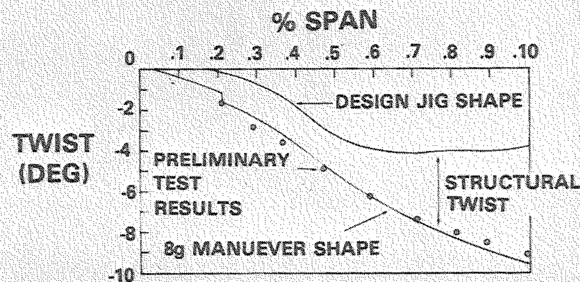
NASA OAST

HIMAT

TWIST/BENDING COUPLING IN WING & CANARD

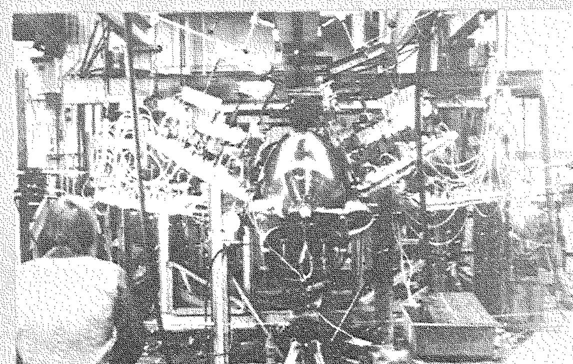


CONCEPT



RESULTS

HIMAT WING WITH LOAD PADS



HIMAT IN LOAD FIXTURE UNDER LOAD

FIGURE 17

NASA **DRONE FOR AERODYNAMIC AND STRUCTURAL TESTING (DAST)** OAST

FLIGHT TEST OF FIRST AEROELASTIC WING

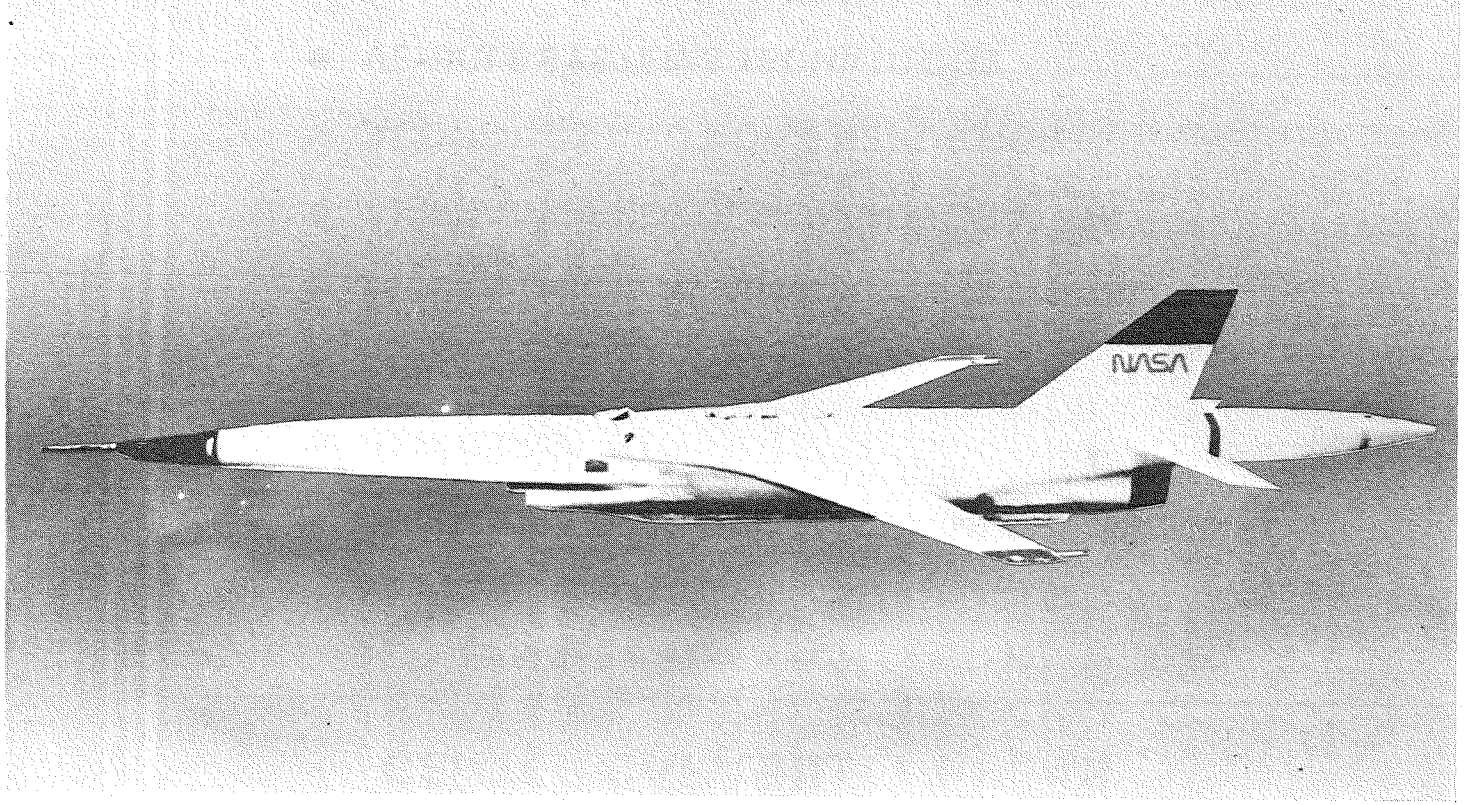


FIGURE 18

CENTER CAPABILITY AREAS

LANGLEY RESEARCH CENTER

- AERODYNAMICS AND FLIGHT MECHANICS
- AEROELASTICITY
- MATERIALS, STRUCTURES AND DYNAMICS
- ELECTRONICS, AVIONICS AND CONTROLS
- AIRFRAME-PROPULSION INTEGRATION
- ACOUSTICS AND NOISE REDUCTION
- VEHICLE SYSTEMS TECHNOLOGY

NASA

FIGURE 19

OAST NASA HQ RP80 4235(1)
7-23-80

CENTER CAPABILITY AREAS/ POTENTIAL APPLICATIONS

LANGLEY RESEARCH CENTER

CAPABILITY AREAS \ POTENTIAL APPLICATIONS	AERONAUTICS					
	GENERIC	G/A	V/STOL	ROTOR-CRAFT	COMM. TRANS.	MILITARY
AERODYNAMICS & FLIGHT MECHANICS	●	●	○	○	●	●
AEROELASTICITY	●	○	○	●	●	●
MATERIALS, STRUCTURES & DYNAMICS	●	●	○	●	●	○
ELECTRONICS, AVIONICS & CONTROLS	●	●	○	○	●	◓
AIRFRAME-PROPULSION INTEGRATION	●	●	○		●	●
ACOUSTICS & NOISE REDUCTION	●	●	○	○	●	○
VEHICLE SYSTEMS TECHNOLOGY		●	○	○	●	◓

● MAJOR EMPHASIS OF ACTIVITY

○ ACTIVITY APPLICABLE

NASA

OAST

NASA HQ RP80 4250(1)
7-23-70

FIGURE 20

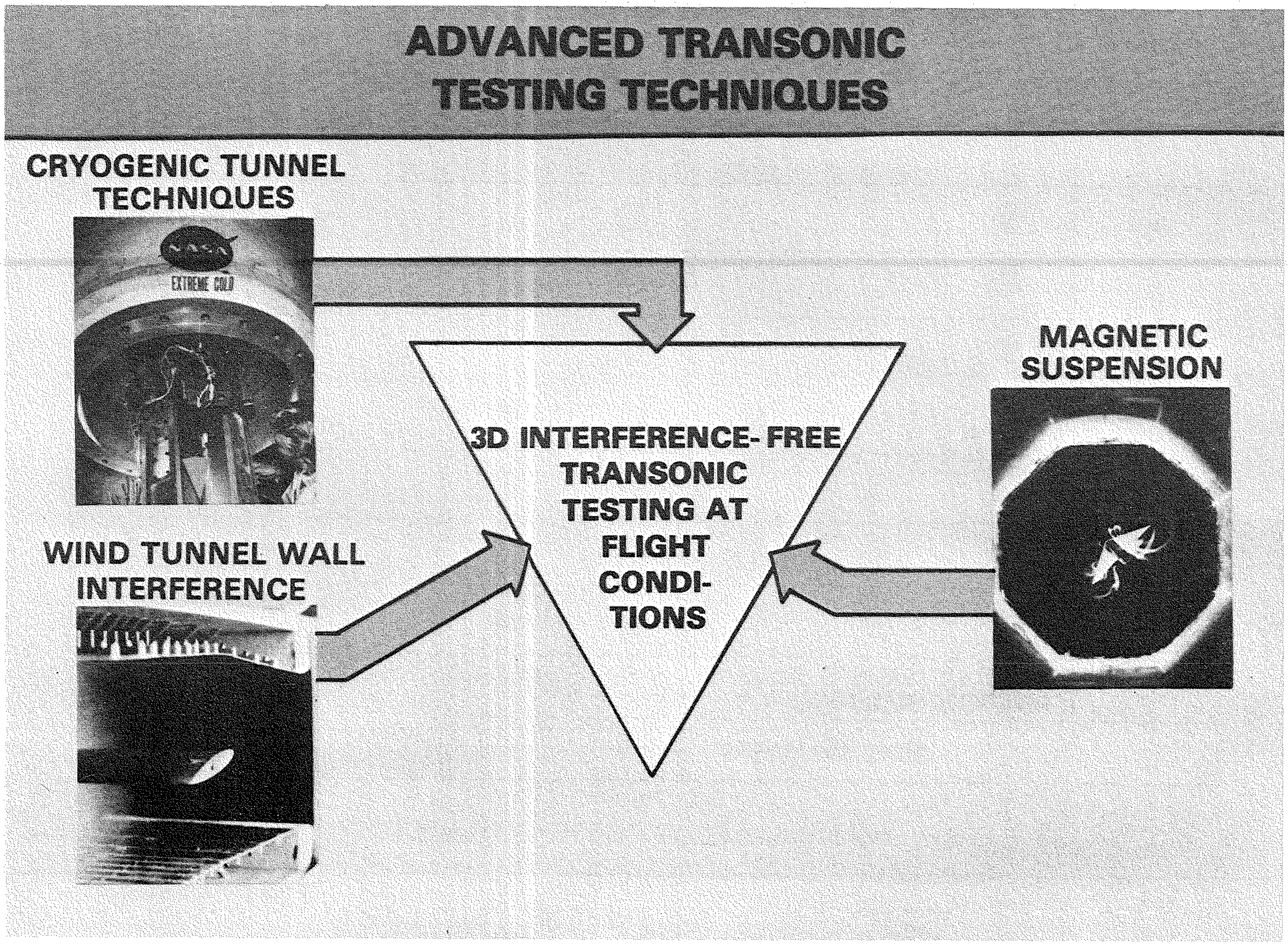

ADVANCED TRANSONIC TESTING TECHNIQUES
CRYOGENIC TUNNEL TECHNIQUES
NASA
EXTREME COLD
WIND TUNNEL WALL INTERFERENCE
3D INTERFERENCE- FREE TRANSONIC TESTING AT FLIGHT CONDI- TIONS
MAGNETIC SUSPENSION

FIGURE 21

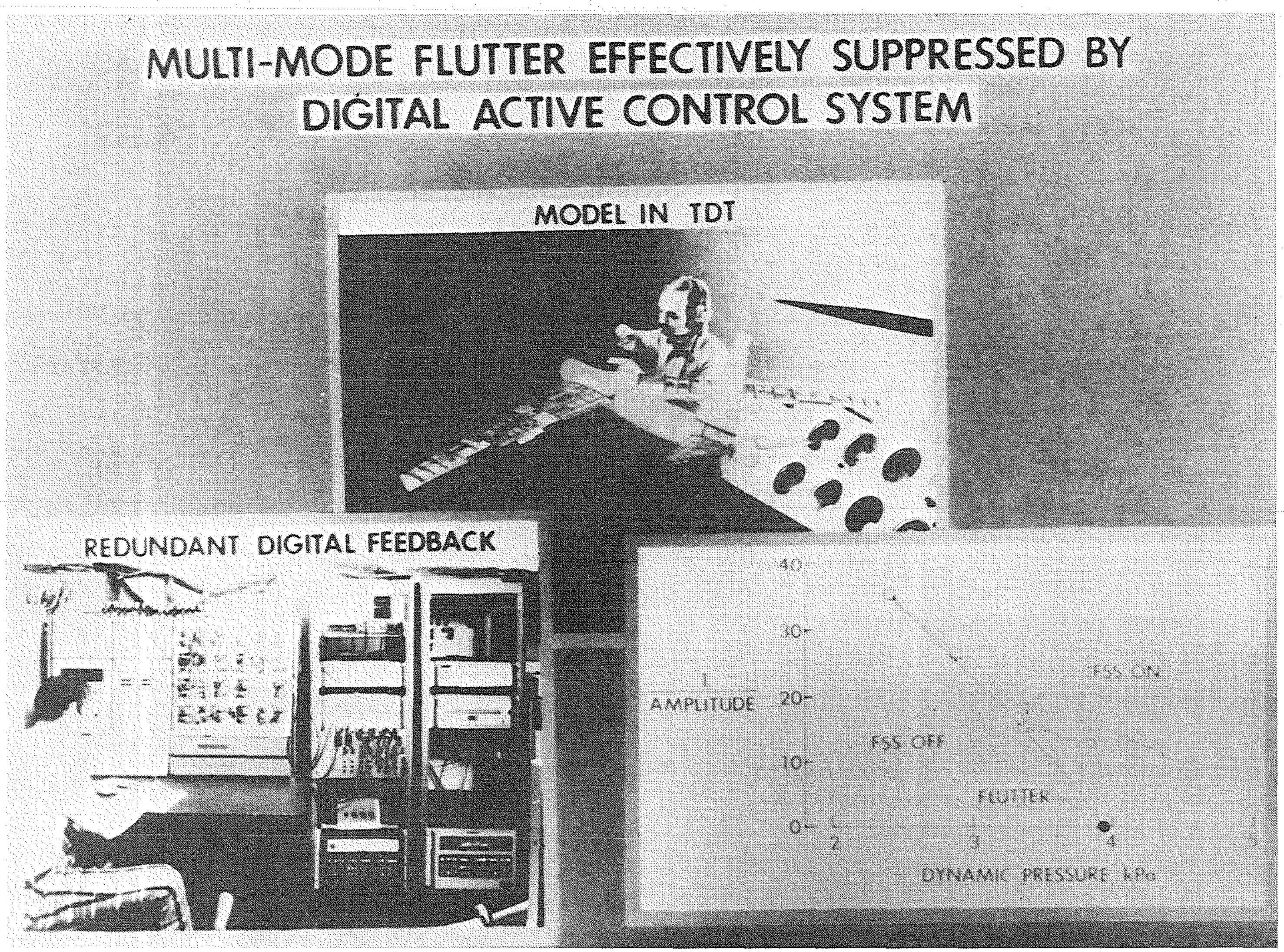

MULTI-MODE FLUTTER EFFECTIVELY SUPPRESSED BY
DIGITAL ACTIVE CONTROL SYSTEM
MODEL IN TDT
REDUNDANT DIGITAL FEEDBACK
40
30
20
10
0
1
AMPLITUDE
FSS ON
FSS OFF
FLUTTER
2
3
4
5
DYNAMIC PRESSURE kPa

FIGURE 22

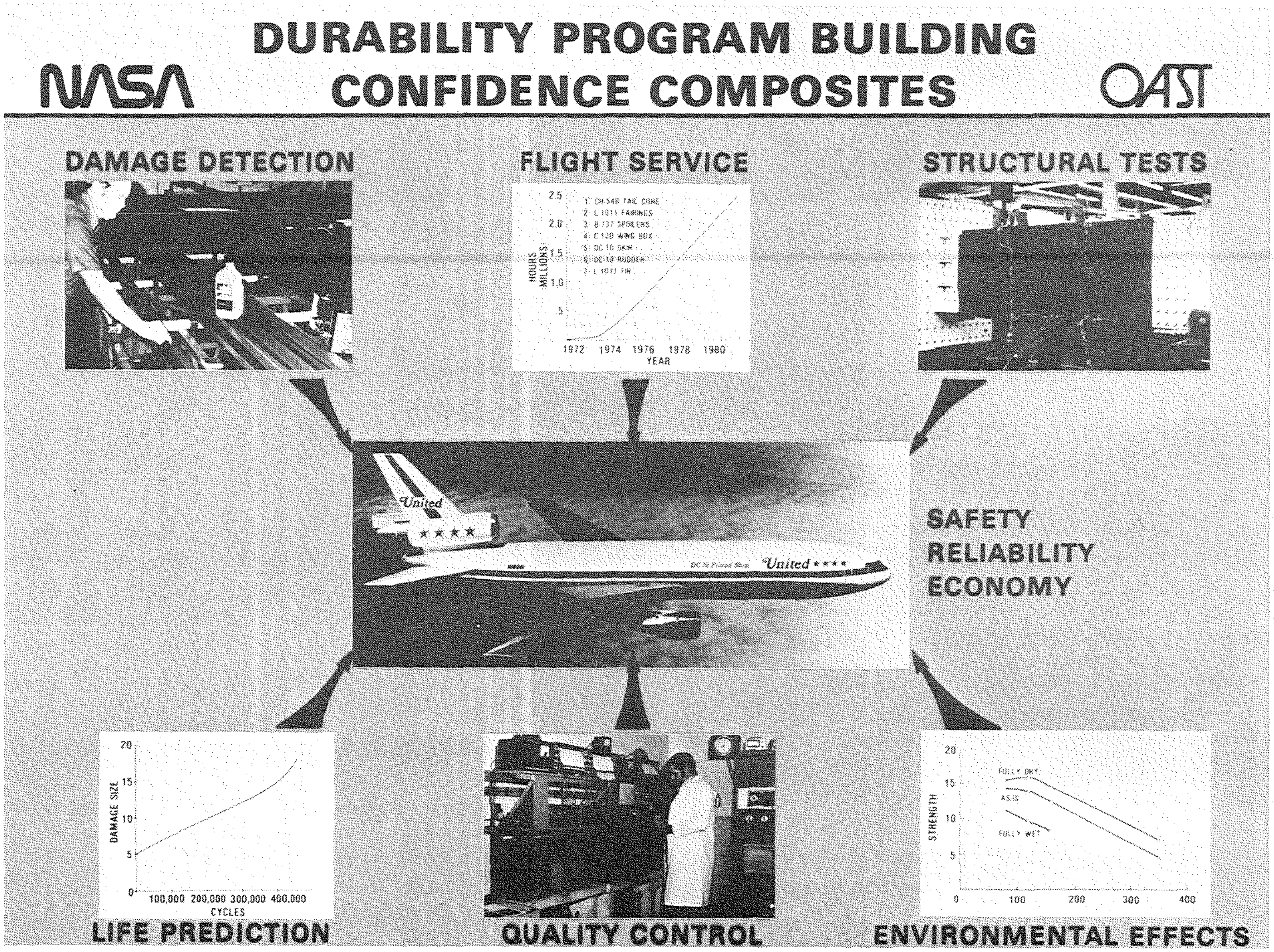

DURABILITY PROGRAM BUILDING
CONFIDENCE COMPOSITES
NASA
OAST
DAMAGE DETECTION
FLIGHT SERVICE
STRUCTURAL TESTS
HOURS MILLIONS
YEAR
1972 1974 1976 1978 1980
United
SAFETY
RELIABILITY
ECONOMY
DAMAGE SIZE
CYCLES
100,000 200,000 300,000 400,000
STRENGTH
FULLY DRY
AS IS
FULLY WET
LIFE PREDICTION
QUALITY CONTROL
ENVIRONMENTAL EFFECTS

FIGURE 23

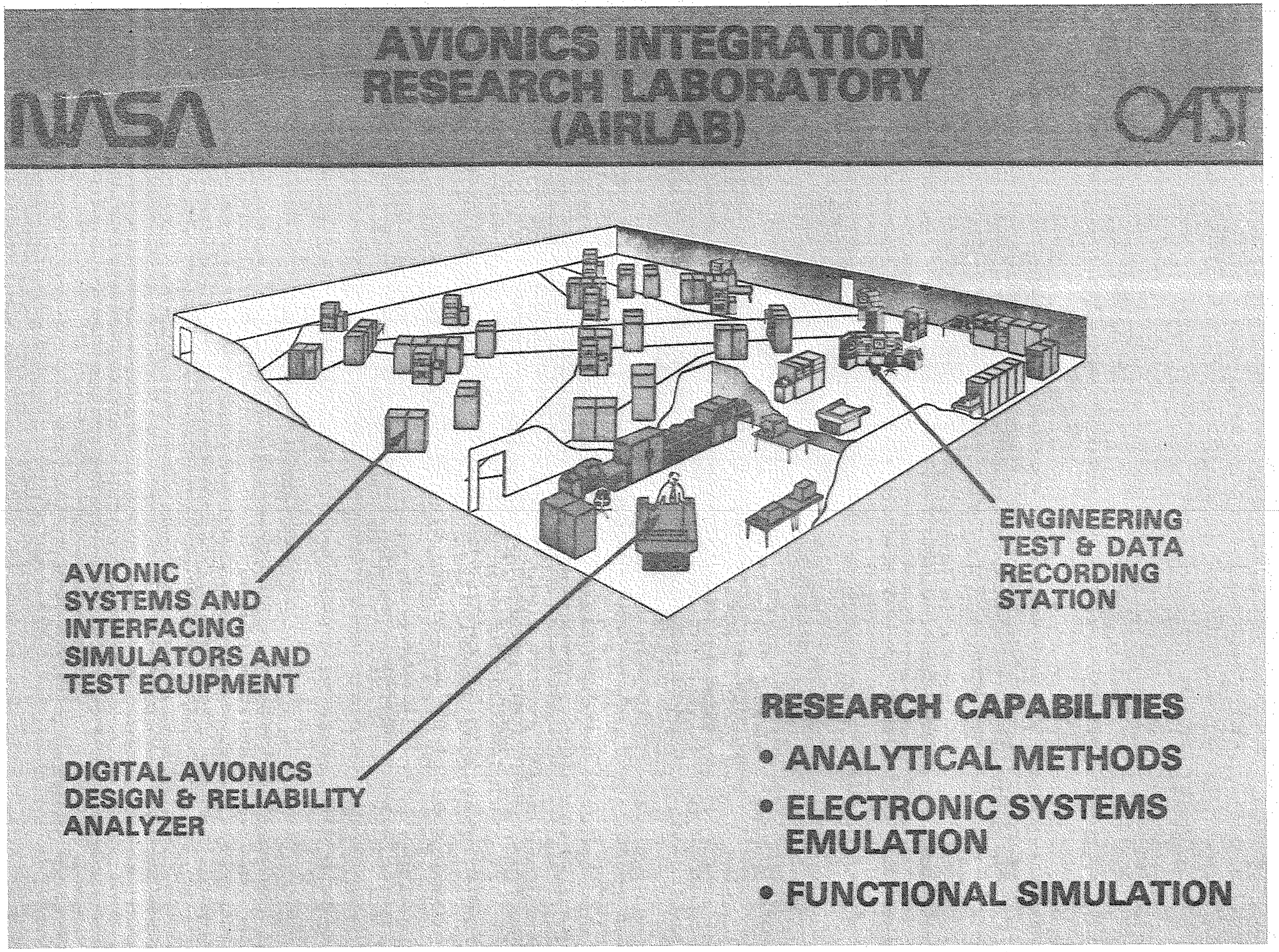

AVIONICS INTEGRATION
RESEARCH LABORATORY
(AIRLAB)
NASA
OAST
AVIONIC SYSTEMS AND INTERFACING SIMULATORS AND TEST EQUIPMENT
DIGITAL AVIONICS DESIGN & RELIABILITY ANALYZER
ENGINEERING TEST & DATA RECORDING STATION
RESEARCH CAPABILITIES
• ANALYTICAL METHODS
• ELECTRONIC SYSTEMS EMULATION
• FUNCTIONAL SIMULATION

FIGURE 24

PROPULSION/AIRFRAME INTEGRATION MODEL

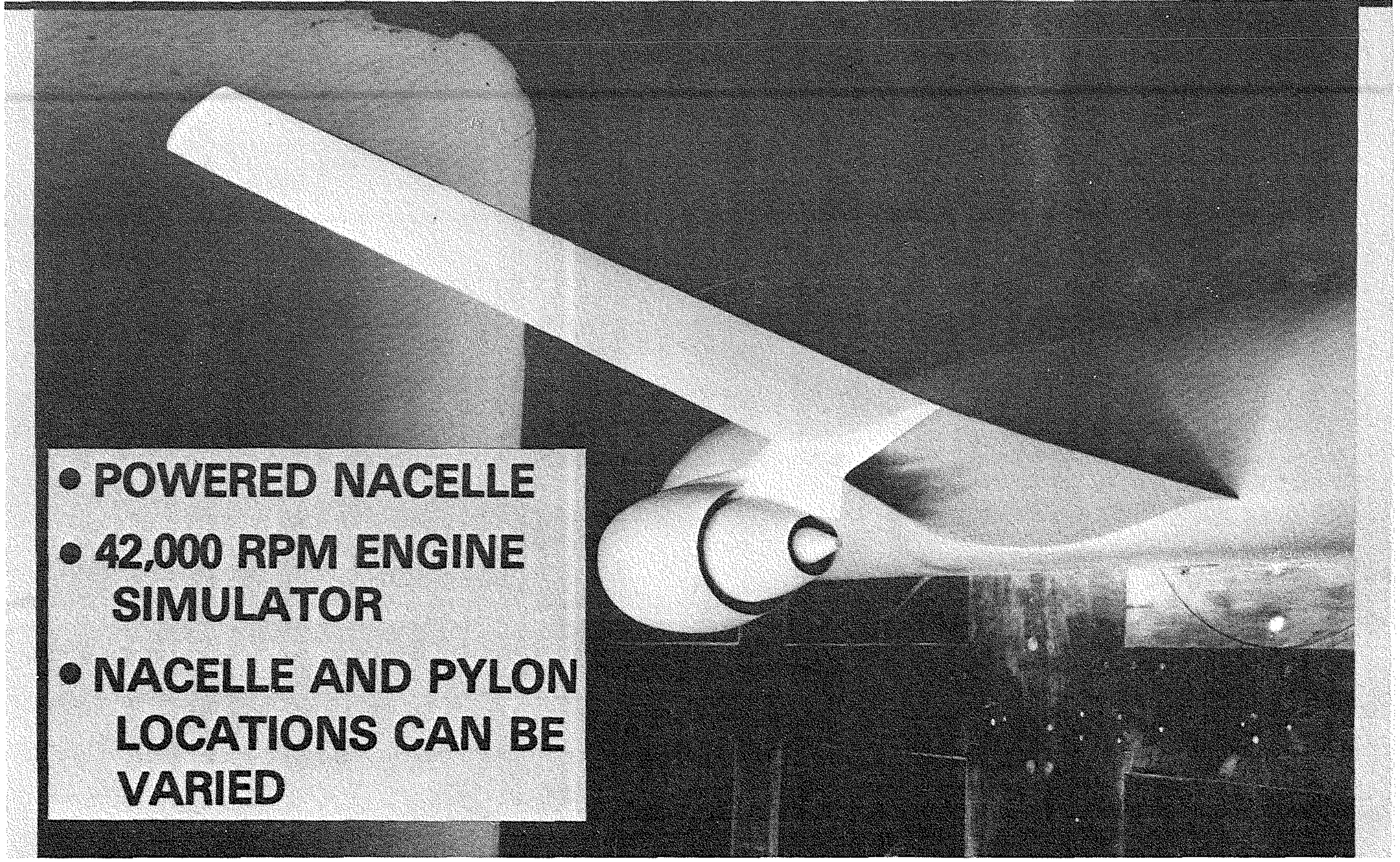


FIGURE 25

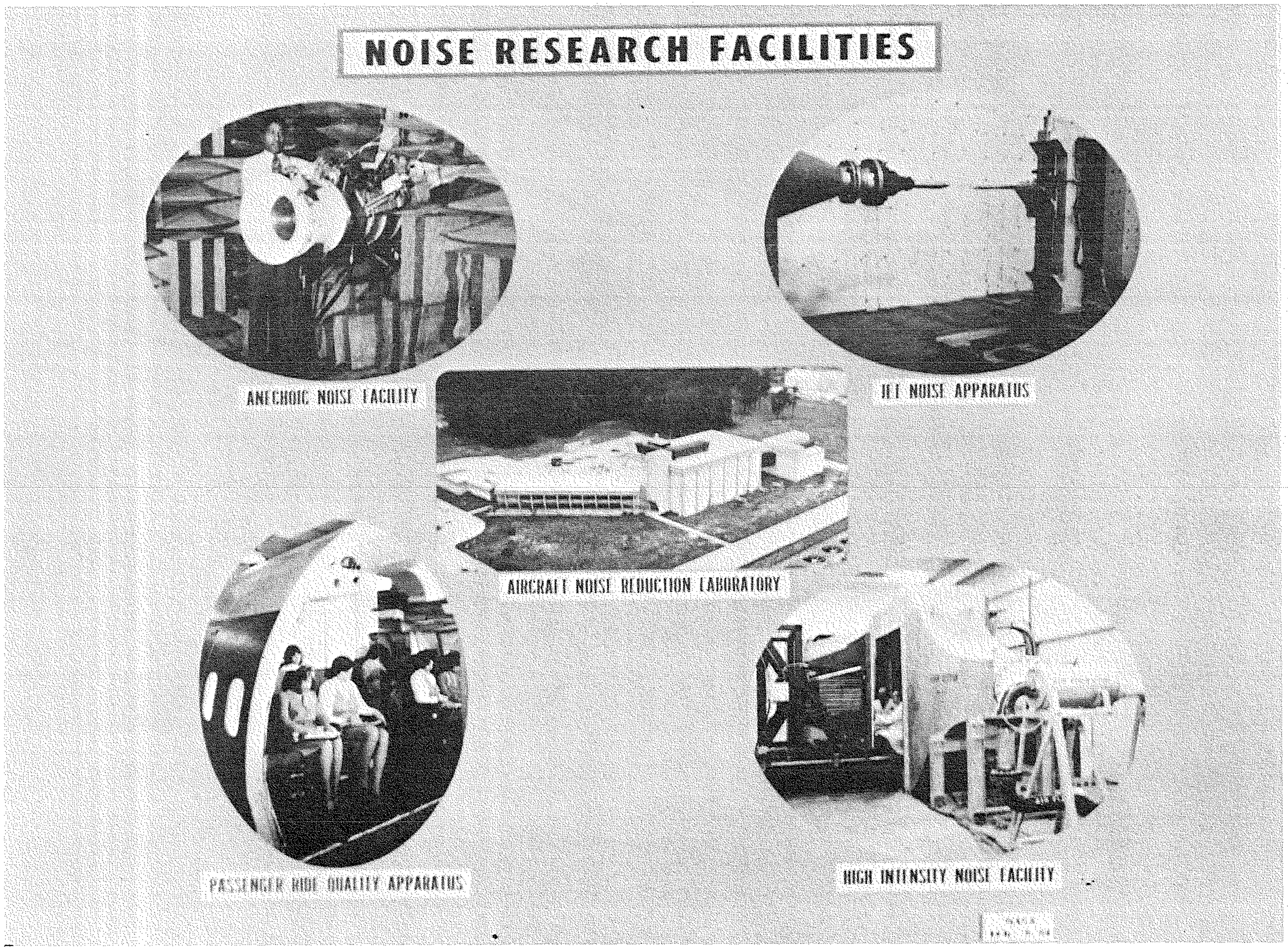

NOISE RESEARCH FACILITIES
ANECHOIC NOISE FACILITY
JET NOISE APPARATUS
AIRCRAFT NOISE REDUCTION LABORATORY
PASSENGER RIDE QUALITY APPARATUS
HIGH INTENSITY NOISE FACILITY

FIGURE 26

DIFFERENTIAL MANEUVERING SIMULATOR

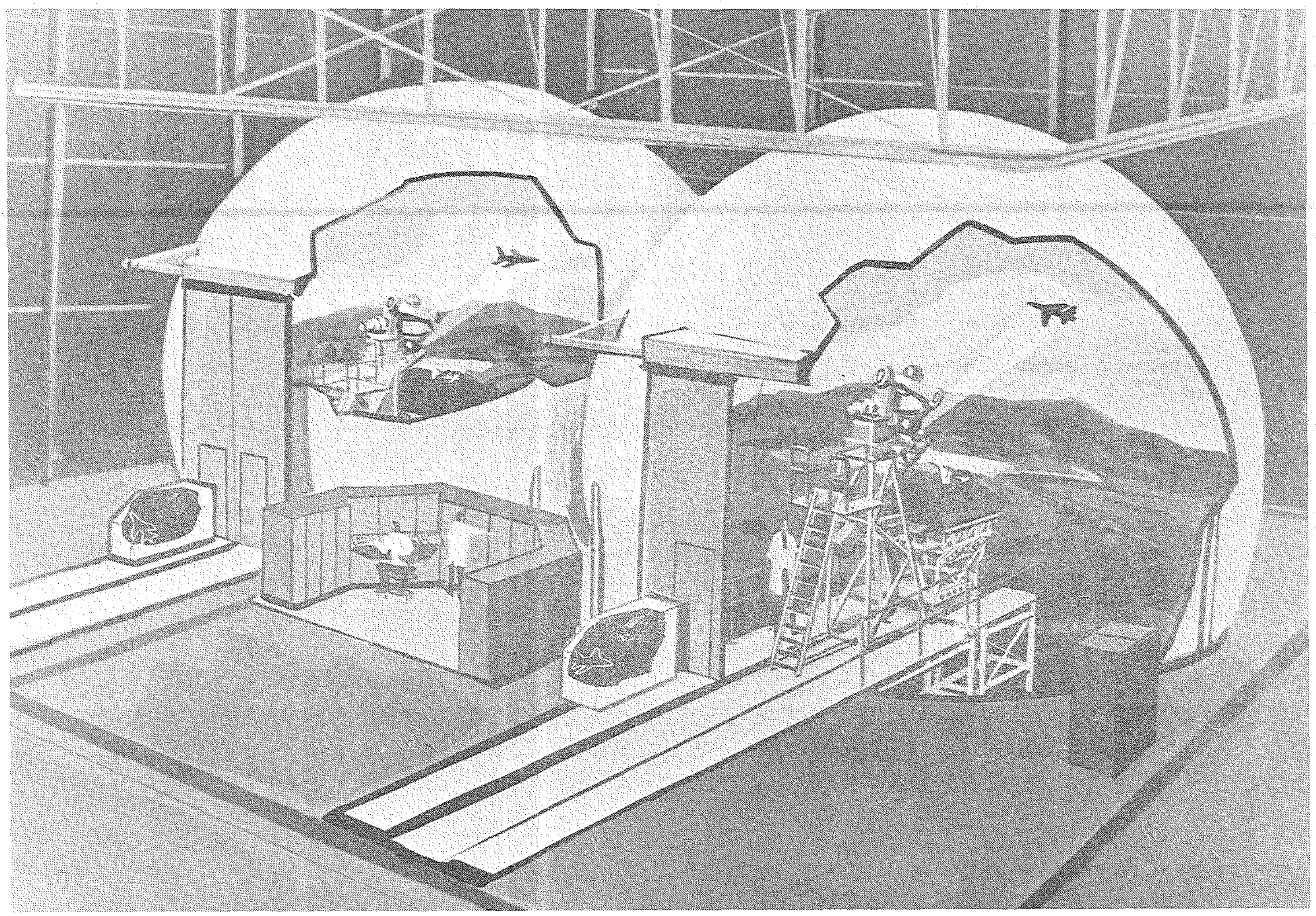
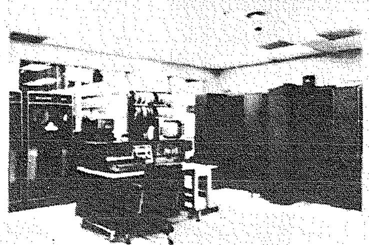


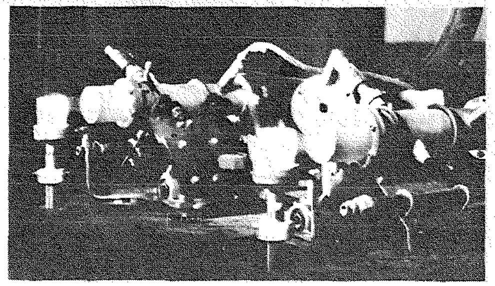
FIGURE 27

LEWIS RESEARCH CENTER

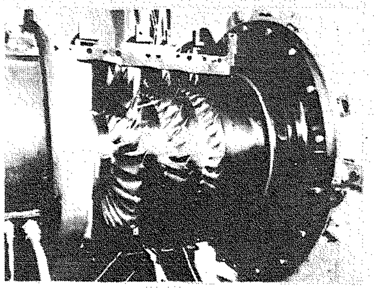
CAPABILITIES FOR AEROPROPULSION R & T



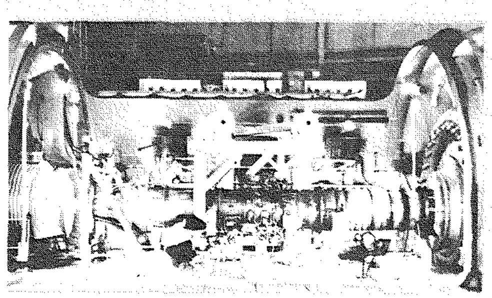
THEORETICAL AND COMPUTATIONAL ANALYSIS



FUNDAMENTAL RESEARCH



COMPONENT R & T



ENGINE & PROPULSION SYSTEM R & T

NASA

OAST NASA HQ RP80 4271(3)
7-23-80

FIGURE 28

CENTER CAPABILITY AREAS/ POTENTIAL APPLICATIONS

LEWIS RESEARCH CENTER

POTENTIAL APPLICATIONS / CAPABILITY AREAS	AERONAUTICS					
	GENERIC	G/A	V/STOL	ROTOR-CRAFT	COMM. TRANS.	MILITARY
THEORETICAL & COMPUTATIONAL ANALYSIS	●	○	○	○	◓	○
FUNDAMENTAL RESEARCH	●	○	○	○	◓	○
COMPONENT R & T		◓	◓	◓	●	○
ENGINE & PROPULSION SYSTEM R & T		◓	◓	◓	●	◓

● MAJOR EMPHASIS OF ACTIVITY

○ ACTIVITY APPLICABLE

NASA

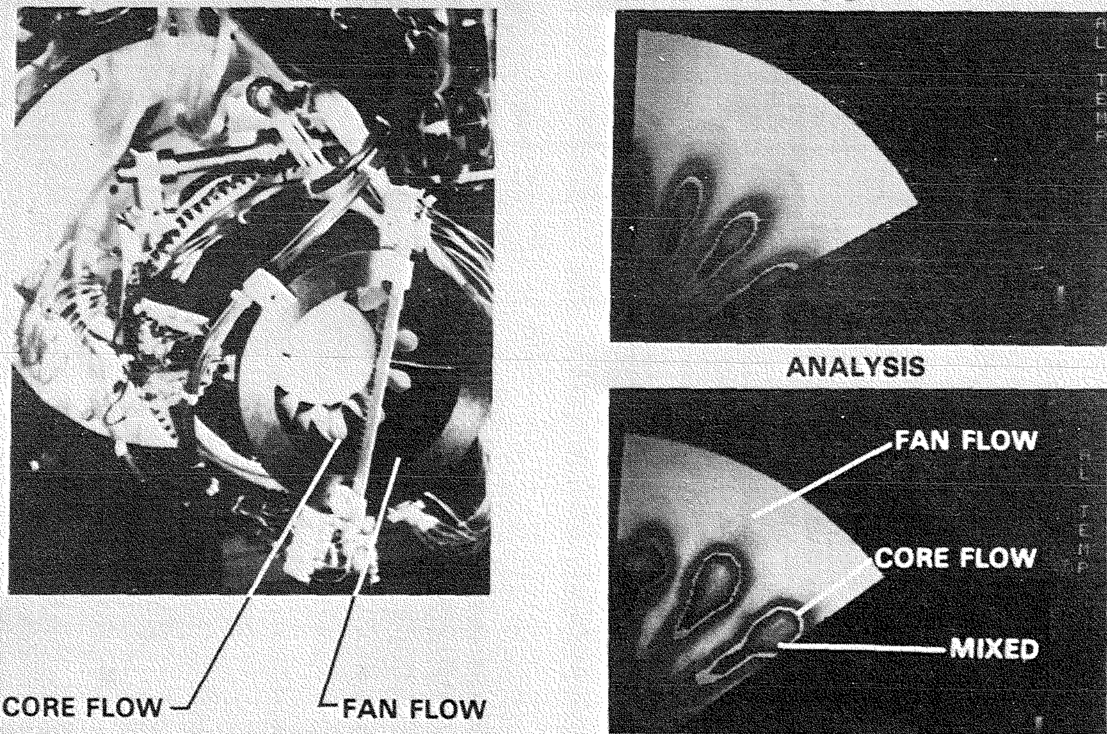
OAST NASA HQ RP80 4249(1) 7-23-80

FIGURE 29

NASA **INTERNAL FLOW COMPUTATIONS** OAST

ENGINE EXHAUST MIXER

EXHAUST PLANE



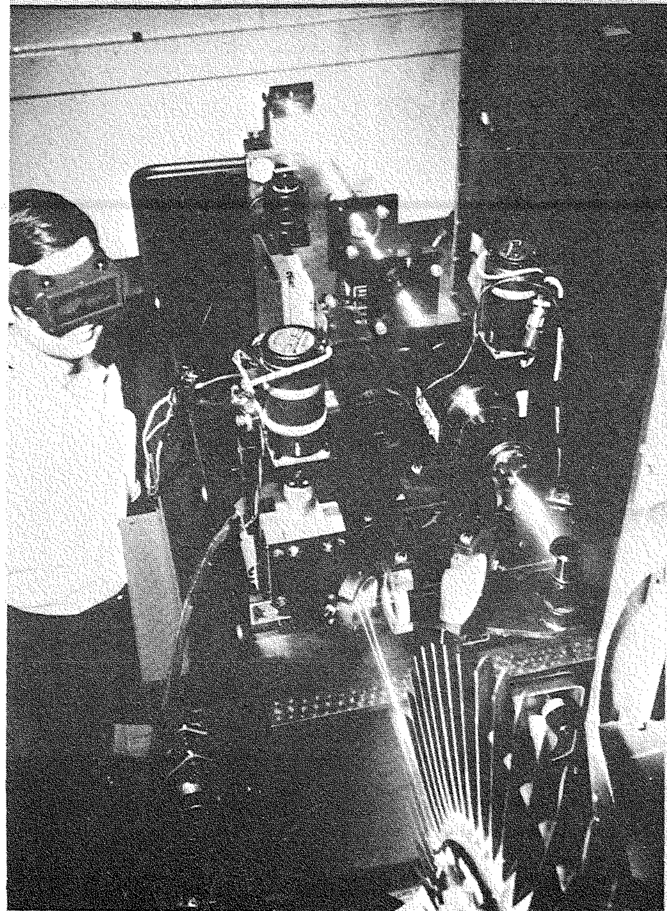
EXPERIMENT

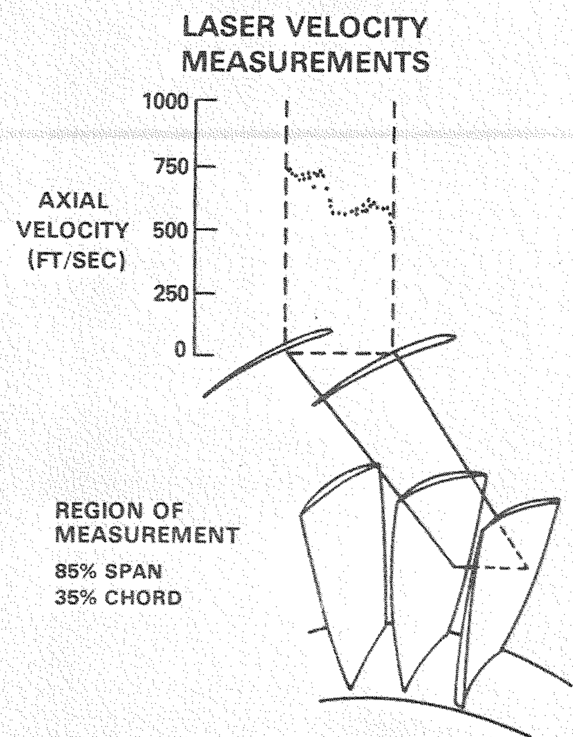
NASA HQ RT80 176(3)
REV. 10 17 79

FIGURE 30

LASER MEASUREMENTS

OAST





NASA HQ RT80-172(3)
REV. 10-22-79

FIGURE 31

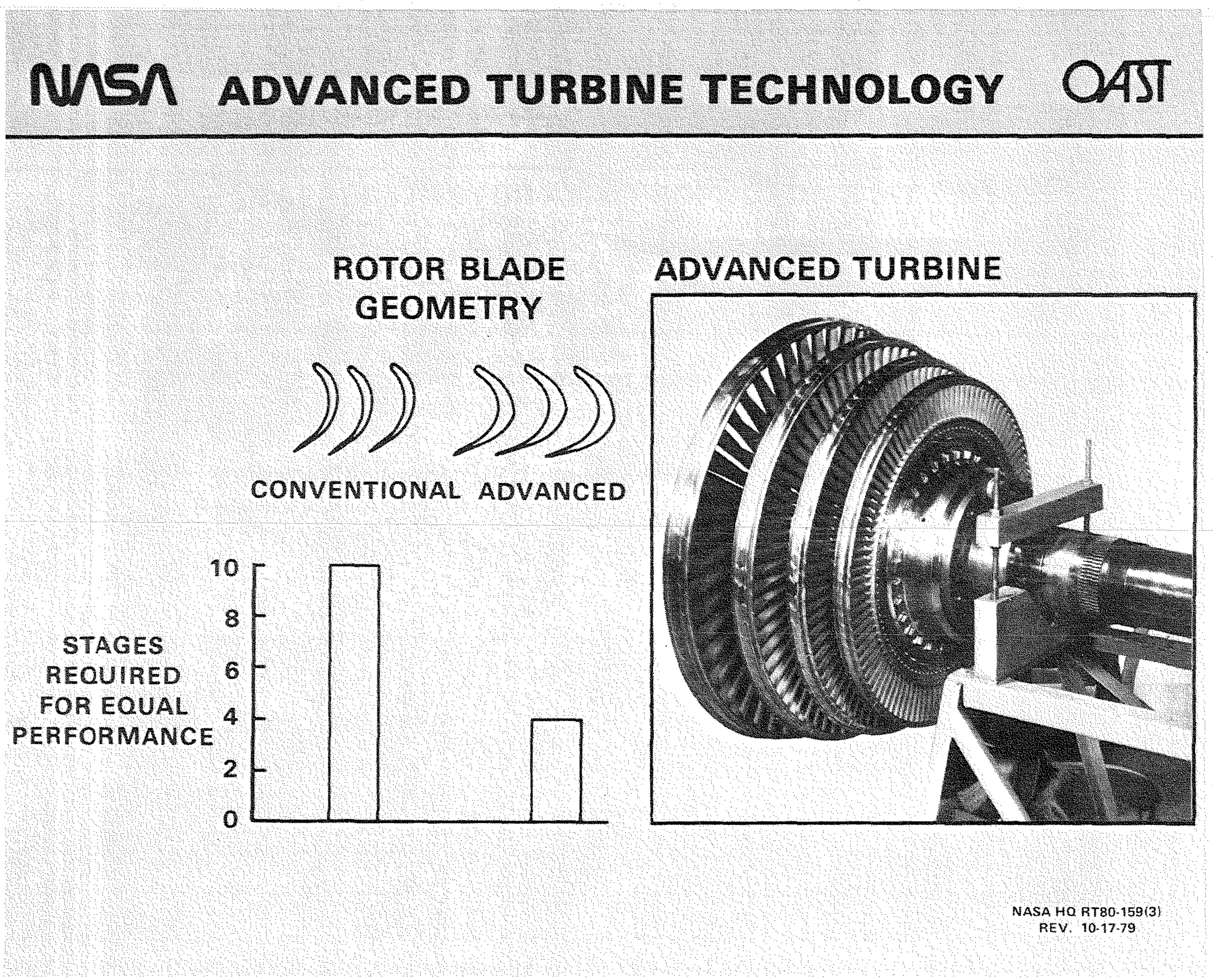

NASA ADVANCED TURBINE TECHNOLOGY OAST
ROTOR BLADE GEOMETRY
CONVENTIONAL
ADVANCED
ADVANCED TURBINE
STAGES REQUIRED FOR EQUAL PERFORMANCE
10
8
6
4
2
0
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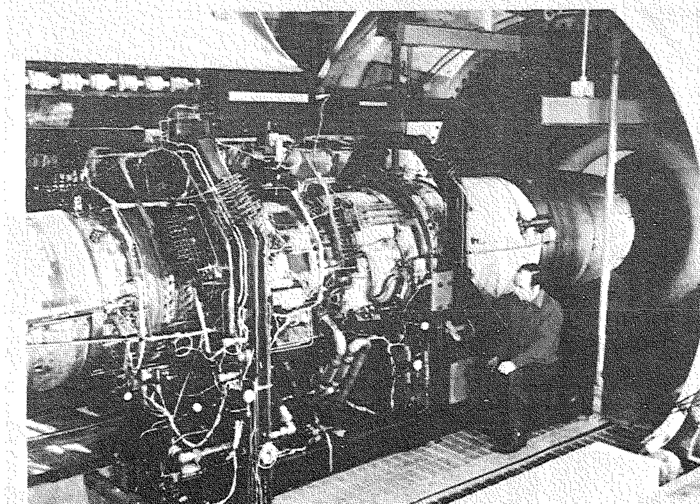
FIGURE 32

MULTIVARIABLE CONTROL TECHNOLOGY

NASA OAST

- ADVANCED CONTROL THEORY
- COMPUTER-AIDED DESIGN

VERIFICATION TESTS



F-100 TURBOFAN IN LEWIS ALTITUDE FACILITY

FAN SPEED RESPONSES

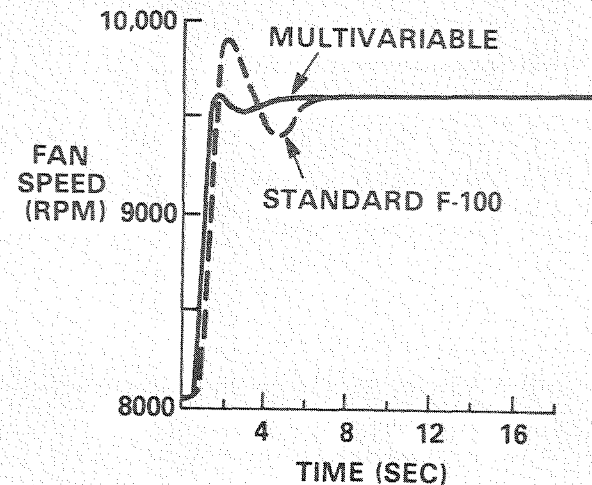


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FIGURE 33

NASA AERONAUTICS CAPABILITIES

	GENERIC	G/A	V/STOL	ROTOR-CRAFT	COMM. TRANS.	MILITARY
FUNDAMENTAL R & T	●	●	◓	●	●	●
SYSTEMS R & T	○	●	○	●	●	●
FACILITIES SUPPORT	●	●	●	●	●	●
FLIGHT TEST	○	◓	●	●	●	●

● MAJOR EMPHASIS OF ACTIVITY

○ ACTIVITY APPLICABLE

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FIGURE 34

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